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Techniques for Estimating MOBILE2 Variables

Energy and Environmental Analysis, Inc.
Arlington, VA

Prepared for

Environmental Protection Agency
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TECHNIQUES FOR ESTIMATING MOBILE2 VARIABLES

FINAL REPORT

Prepared for:

TEST AND EVALUATION BRANCH
EMISSION CONTROL TECHNOLOGY DIVISION
OFFICE OF MOBILE SOURCE AIR POLLUTION CONTROL
OFFICE OF AIR, NOISE AND RADIATION
U.S. ENVIRONMENTAL PROTECTION AGENCY
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The purpose of this report is to develop a general users information package for selected MOBILE2 input variables. Specifically, estimation techniques are needed so that users from state and local agencies can use MOBILE2 to produce mobile source emission factor estimates appropriate to their particular areas. This report describes techniques that can be used to estimate certain MOBILE2 input variables. These techniques are designed to assist users who do not possess information on one or more of the MOBILE2 input variables readily available and need guidance on potential techniques.

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1. INTRODUCTION

The purpose of this report is to describe work performed by EEA, Inc. for Task Order No. 1 of EPA Contract No. 68-03-2888. The objective of this task order was to develop a general users information package for selected MOBILE2 input variables. Specifically, estimation techniques are needed so that state and local agency users can use MOBILE2 to produce mobile source emission factor estimates appropriate to their particular areas. This report describes techniques that can be used to estimate certain MOBILE2 input variables. These techniques are general in nature, and are not specific to any given region or emission factor application analysis. These techniques are designed to assist user's who do not have information on one or more of the MOBILE2 input variables readily available and need guidance on potential techniques. If other techniques have been developed locally for estimating these variables, then the techniques presented here need not be used. In most uses, the techniques presented in this report are based on nationwide data and should be considered appropriate for both urban and rural areas. Where data specific to urban areas are used, they are specifically identified as such.

1.1 REPORT ORGANIZATION

Table 1-1 shows the MOBILE2 input variables and vehicle types discussed in this report. The vehicle type abbreviations shown at the bottom of the table are those used throughout the report. The report is organized so that estimation techniques for each variable are presented in separate sections. Within each section, estimation techniques are presented separately for each vehicle type. Sometimes more than one possible estimation technique is described for each vehicle type. In those cases, MOBILE2 users can choose the technique most applicable to their situation.

TABLE 1-1

SELECT MOBILE2 INPUT VARIABLES BY VEHICLE TYPE

	Input Variables	Vehicle Type*
1.	Mileage accumulation by age	All vehicle types
2.	Vehicle registrations by age	All vehicle types
3.	Average humidity levels (grains of water/lb of dry air)	Independent of vehicle type
4.	Average temperature (F)	Independent of vehicle type
5.	Total VMT fractions	All vehicle types
6.	Average trips/day by age	All vehicle types
7.	Average percent VMT in cold/hot starts for catalyst and/or non-catalyst	All vehicle types
8.	Average number of vehicles with air conditioning by model year	All except MC, HDGV, and HDDV
9.	Average fraction trips/day by age with either extra load or trailer towing	All except MC, HDGV, and HDDV
10.	Average load/CID distributions trip/model year	HDDV and HDGV

*LDGV: Light-Duty Gasoline-Powered Vehicles
LDDV: Light-Duty Diesel-Powered Vehicles
LDGT1: Light-Duty Gasoline-Powered Trucks (<6001 lbs GVW)
LDGT2: Light-Duty Gasoline-Powered Trucks (>6000 lbs & <8501 lbs GVW)
LDDT: Light-Duty Diesel-Powered Trucks (<8501 lbs GVW)
HDGV: Heavy-Duty Gasoline-Powered Vehicles (<8500 lbs GVW)
HDDV: Heavy-Duty Diesel-Powered Vehicles (>8500 lbs GVW)
MC: Motorcycles

Until 1977, diesel-powered vehicles did not make up a significant fraction of the vehicle population except in the heavy-duty vehicle category. Therefore, travel characterizations are not available for light-duty diesel-powered vehicles and trucks. Thus, it has been assumed in this report that light-duty diesels have the same characteristics as their gasoline-powered counterparts. The only section of the report where specific light-duty diesel information is presented is the section on vehicle registrations by age.

1.2 DATA SOURCES (GENERAL)

In order to accurately estimate the Table 1-1 variables for each area, data sources other than this document will be needed. To facilitate selection of the appropriate references for use in estimating selected variables, a brief explanation of the useful information included in each of a number of publications is presented below. Full references for these documents are listed on the last page in Section 1.

1. Nationwide Personal Transportation Study

   This is a series of 11 reports published by the U.S. Department of Transportation/Federal Highway Administration from April 1972 to December 1974. Each report discusses a different aspect of the data collected during the Nationwide Personal Transportation Survey of 1969-1970. That survey was based on a multi-stage probability sample of housing units located in 235 sample areas, comprising 485 counties and independent cities, representing every State and the District of Columbia. A total of approximately 6000 households were interviewed. Primarily automotive travel characteristics were surveyed. The titles of the 11 reports are listed below:

   - Automobile Occupancy
   - Annual Miles of Automobile Travel
   - Seasonal Variations of Automobile Trips and Travel

- Transportation Characteristics of School Children
- Availability of Public Transportation and Shopping Characteristics of SMSA Households
- Characteristics of Licensed Drivers
- Household Travel in the United States
- Home-to-Work Trips and Travel
- Mode of Transportation and Personal Characteristics of Tripmakers
- Purposes of Automobile Trips and Travel
- Automobile Ownership

An updated version of the Nationwide Personal Transporation Study (NPTS), using data collected in 1977 should be available in late 1980.

Applicability: Vehicle Registrations by Age
Vehicle Miles Traveled

Availability: U.S. DOT--Federal Highway Administration. (copies available)

2. Census of Transportation, 1972 Truck Inventory and Use Survey

The 1972 Truck Inventory and Use Survey (TIUS) provides data on the physical and operational characteristics of the nation's truck population. It was based on a probability sample of private and commercial trucks registered in the U.S. during 1972. Systematic sampling techniques were used in the 1972 TIUS. The TIUS is based on a stratified (light vs. heavy trucks) probability sample of 114,000 trucks. The description of the 1972 TIUS survey consists of 52 reports - one for each state, D.C. and the nation. The 1972 TIU surveys were benchmarked to Federal Highway Administration totals of private and commercial truck registrations as reported in Highway Statistics, MV-1.

Applicability: Vehicle Registrations by Age
Mileage Accumulation by Age

Availability: Depository Libraries (for review)
U.S. Department of Commerce - district offices (for review)

U.S. Bureau of the Census - regional offices (for review)
U.S. Government Printing Office (for purchase)

3. Census of Transportation, 1977 Truck Inventory and Use Survey

The 1977 TIUS is based on a probability sample (using random sampling techniques) of private and commercial trucks registered during 1977. The 1977 TIUS (at the national level) was based on a stratified (small vs. large) probability sample of 117,000 trucks which was drawn from approximately 28 million registrations on file throughout the U.S. Unlike the 1972 TIU survey, the 1977 TIU survey was not benchmarked to the Federal Highway Administration registration totals.

Printed reports include a U.S. summary and a separate report for each State and the District of Columbia. Public-use computer tapes are available for users who wish to summarize, rearrange, or process large amounts of data. The tapes, with corresponding technical documentation, may be purchased for $80 per reel. The computer tapes contain data on make, model, weight, and type of ownership for individual trucks in the probability sample. A record for each of approximately 96,000 vehicles is contained on the tape.

Applicability: Vehicle Registrations by Age
Mileage Accumulation by Age

Availability: U.S. Bureau of the Census (regional offices)
U.S. Department of Commerce (district offices)
(above are for reference)
Government Printing Office (for purchase)
Bureau of Census, Data User Services Division (public use tape)

4. The Development of an Emission and Fuel Economy Computer Model for Heavy-Duty Trucks and Buses, Jambekar and Johnson

The purpose of this study was to examine the problem of truck emissions, fuel usage and the economic implications

of future truck and bus population service in the U.S. and particular urban areas. The information in this report was based on data obtained primarily from three published sources: The 1972 Census of Transportation, Truck Inventory and Use Survey, Motor Truck Facts (1938-1975) published by the Motor Vehicle Manufacturing Association of the U.S. and publications by Tingley and Johnson. This report provides methodologies to estimate accumulated mileage and registration by age for trucks.

Applicability: Mileage Accumulation by Age
Vehicle Registrations by Age

Availability: U.S. Environmental Protection Agency (limited copies available)

5. Survey of Motorcycle Ownership, Usage and Maintenance The Gallup Organization, Inc.

This report describes a study designed to determine motorcycle ownership, usage and maintenance patterns nationwide. The survey was conducted by the Gallup Organization for the Motorcycle Industry Council, Inc., via interviews with a national sample of 4,187 primary motorcycle users. Interviews were conducted from May 15 - June 2, 1974, and 4800 motorcycles were reported upon.

Applicability: Motorcycle Mileage Accumulation by Age

Availability: The Motorcycle Industry Council, Inc. Newport Beach, CA. (limited copies available)

6. Motorcycle Statistical Annual, Motorcycle Industry Council, Inc.

The Motorcycle Industry Council, Inc. (MIC) gathers information on motorcycle use, ownership and maintenance and compiles these data to provide comprehensive motorcycle statistics. The Motorcycle Statistical Annual is one of their yearly publications describing these data. Each table in the annual credits the government or private organization which provided the information.

Applicability: Mileage Accumulation by Age
Vehicle Registrations by Age
Vehicle-Miles Traveled
Vehicle Trips per Day

Availability: Motorcycle Industry Council, Inc.,
Administrative Office
Government Relations Office, Newport
Beach, CA.
(for purchase)

7. Motor Vehicle Facts and Figures, 1979
Motor Vehicle Manufacturers Association

The Motor Vehicle Manufacturers Association compiles data on automobile and truck production and registrations, motor vehicle use and ownership, and economic impacts related to motor vehicle production and use. The information provided in the tables and charts in the MVMA Facts and Figures report is compiled by the MVMA from data collected from their own efforts and from other organizations. Each table and chart credits the organization(s) responsible for the data collection. The MVMA Motor Vehicle Facts and Figures report contains statistics formerly published in the MVMA Motor Truck Facts.

Applicability: Vehicle Registrations by Age
Vehicle Miles Traveled

Availability: Motor Vehicle Manufacturers Association,
Detroit, MI.
(copies available)

8. Census of Population and Housing, Bureau of the Census

The 1970 Census of Population and Housing is a compilation of data on population household characteristics that was collected by a combination of 100 percent and random samples. Data on population and number of households are based on 100 percent sampling and are contained in a volume which consists of separate reports for the U.S., each of the 50 states, the District of Columbia, Puerto Rico, Guam, Virgin Islands, American Samoa, and the Trust Territory of the Pacific Islands. For each of these 57 areas, the population and counts are presented by state, counties, standard metropolitan statistical

areas (SMSA), urbanized areas, county subdivisions, incorporated places, and census designated places, in Chapter A of the Population Census Report, Volume I. Data on household income and automobile ownership are based on a sampling distribution and are reported in the Housing Census Report, Volume I -- Characteristics of Housing Units, Chapter B. The information in this report is listed by states, counties, SMSA's, urbanized area, places of 2500 or more, Indian Reservations, and Alaska's Native Villages.

The 1980 Census of Population and Housing will contain the same type of information as the 1970 census. The preliminary population and housing unit counts will be published between August and October, 1980. Chapter A of the Population Census Report, Volume I will be issued December 1980 - April 1981, and Chapter B of the 1980 Housing Census Report, Volume I, will be issued September 1981 - April 1982.

Applicability: Vehicle Registrations by Age
Vehicle Miles Traveled
Vehicle Trips per Day

Availability: U.S. Bureau of the Census
U.S. Department of Commerce
(for sale by U.S. Government Printing Office)

9. Wards Automotive Yearbook, 1979

Wards Automotive Yearbook is published by Wards Communications, Inc. The yearbook contains statistics on both automobiles and trucks.

Applicability: Vehicle Registrations by Age
Air Conditioning Units per Vehicle Type

Availability: Ward's Communications, Inc., Detroit, MI.
(for sale)

10. Highway Statistics 1978, U.S. Department of Transportation, Federal Highway Administration

This publication was prepared by the Highway Statistics Division of the Federal Highway Administration. It

brings together annual series of selected statistical tabulations relating to highway transportation in three major areas: (1) highway use, (2) highway finance, (3) the highway plant (changing characteristics of the mileage of public highways, roads and streets in the nation). Statistics in this report were analyzed and reported on a calendar year basis using procedures that provide comparability of values among states.

Applicability: Vehicle Miles Traveled

Availability: U.S. Department of Transportation (copies available)
U.S. Department of Commerce

11. Automotive News 1979 Market Data Book Issue

Automotive News is published weekly except semi-monthly the fourth week in April, when the Market Data Book Issue is published. Automotive News is the weekly newspaper of the industry. The Market Data Book Issue contains sales and registration estimates (sometimes broken down by state) for both automobiles and trucks. The two major sources of data for this publication are R. L. Polk and Co., and the Motor Vehicle Manufacturers Association.

Applicability: Vehicle Registration Fractions by Age
Heavy-Duty Vehicle CID/Load Characteristics

Availability: By subscription from the Crain Automotive Group, Inc., Detroit, MI.

12. Recreation Vehicle Industry Association, Facts and Trends, 1978

This annual publication includes data on RV shipments to states by year. RV shipments are broken down into four different classes of recreational vehicles.

Applicability: Extra Load and Trailer Towing Trips

Availability: Recreation Vehicle Industry Assoc., Chantilly, VA. (copies available)

1.3 DATA SOURCES (STATE AND LOCAL)

Many state and local agencies collect data that are related to the MOBILE2 input variables. Some of these agencies prepare estimates of the input variables for specific localities. Several types of agencies located in various areas across the U.S. were contacted to determine the extent of information available and the difficulty associated with collecting the necessary information. Other agencies in these areas may have similar information, thus we have included only examples to aid the user in determining what kinds of agencies should be contacted. Of the 10 agencies contacted, the following provided information that could be useful in estimating the registration, mileage, vehicle-miles traveled, and trip input variables for specific localities:

- Southwest Pennsylvania Regional Planning Commission (Pittsburgh)
  - registrations
  - trips
  - VMT
- Montgomergy-Greene County Transportation Development Planning Program (Dayton, Ohio)
  - registrations
  - trips
  - VMT
- Michigan Department of State (Lansing)
  - registrations
  - trips
  - VMT
- Southeast Michigan Council of Governments
  - VMT
- Chicago Area Transportation Study
  - VMT
  - trips

- Delaware Valley Regional Planning Commission (Philadelphia)
  - VMT
  - trips
  - registrations
- Southern California Association of Governments
  - mileage
  - VMT
  - registrations
- Atlanta Regional Council
  - mileage
  - trips
  - registrations
  - VMT
- DC Council of Governments
  - registrations
  - VMT
  - trips
- New York State Department of Transportation (Albany)
  - trips
  - VMT
  - mileage

Not all of the above agencies have data in the exact form needed to input into MOBILE2. For instance, not all trip data are broken down by vehicle type and not all registration data are available by age. However, the data available are specific to localities, counties, or states, and therefore could be useful in estimating emissions. They can be used either in the form they are in, or in conjunction with other available data for estimating registrations by age, mileage accumulation by age, VMT or trip data for localities.

All of the agencies listed above provided information free of cost. Some agencies mailed samples of pertinent data. Therefore, the data

acquisition will not be costly, but depending on the extent of data needed, the acquisition could entail hours on the telephone and days to weeks of waiting for information in the mail.

REFERENCES FOR SECTION 1

Automotive News. 1979 Market Data Book Issue. Crain Automotive Group, Inc., Detroit, MI.

Jambekar, A., and Johnson, J. 1977. The Development of an Emission and Fuel Economy Computer Model for Heavy-Duty Trucks and Buses. Michigan Technological University. Houghton, MI.

Motorcycle Industry Council, Inc. 1979. Motorcycle Statistical Annual. Newport Beach, CA.

Motor Vehicle Manufacturers Association. 1979. Motor Vehicle Facts and Figures. Detroit, MI.

Recreation Vehicle Industry Association. 1979. Facts and Trends/1978. Chantilly, VA.

The Gallup Organization, Inc. January 1975. Survey of Motorcycle Ownership, Usage, and Maintenance. Conducted for the Motorcycle Industry Council, Inc. Newport Beach, CA.

U.S. Department of Commerce. 1970. Census of Population and Housing. Bureau of the Census. Washington, D.C.

U.S. Department of Commerce. 1972. Truck Inventory and Use Survey, Census of Transportation. Bureau of the Census. Washington, D.C.

U.S. Department of Transportation. April 1972. Nationwide Personal Transportation Study. Report Nos. 1-11. Federal Highway Administration. Washington, D.C.

U.S. Department of Transportation. 1978. Highway Statistics. Federal Highway Administration. Washington, D.C.

Ward's Communications, Inc., 1979. Wards Automotive Yearbook. Detroit, MI.

2. MILEAGE ACCUMULATION BY AGE

The ability to predict future emission rates is dependent on a knowledge of emission standards and a knowledge of vehicle emission deterioration as a function of age and mileage. Therefore, determining the distribution of mileage accumulation by age is an important input to a mobile source emission factor model. There are various ways of estimating mileage accumulation by age. They will be presented separately for each vehicle type. None of the techniques listed should be assumed superior to those normally used. The techniques described should only be implemented if the user of MOBILE2 does not have access to any other estimates.

2.1 LIGHT-DUTY VEHICLES

The following subsections describe the method by which mileage accumulation by age for light-duty vehicles can be approximated from national data. This method can be applied to estimate mileage accumulation by age for both light-duty gasoline and diesel-powered vehicles. Section 2.1.1 describes the data sources. Section 2.1.2 describes the estimation techniques, and Section 2.1.3 discusses the problems posed by this method.

2.1.1 Data Sources

The U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA) calculated light duty vehicle mileage accumulation by age using 1979 and earlier data (from R. L. Polk). These are presented in Section 2.1.2 and should be updated from time to time. It is advisable that mileage accumulation data be collected on a local or state level, rather than on a national level where possible. Various state/city agencies collect these data for specific cities, counties or

SMSA's. For instance, the Michigan Department of State compiles mileage accumulation by age data by county from driver surveys. The California Association of Governments, and the Atlanta Regional Council have similar data. The NYS Department of Transportation has these data by county; however, these data were obtained from R. L. Polk. Therefore, the MOBILE2 users should contact the corresponding agency located in their state or local area to determine the available information. If no local data on mileage accumulation by age are available, then the national estimates can be used. Some additional sources of mileage accumulation by age data, other than those presented in Section 2.1.2, are the Nationwide Personal Transportation Study (U.S. DOT, 1972) and the U.S. Department of Transportation. However, the most recent data from the sources mentioned or from other available sources should be used in MOBILE2.

2.1.2 Estimation Technique

The NHTSA lists annual mileage accumulation by age for all types of light-duty vehicles. These estimates can be used to estimate mileage accumulation by age for any locality by adding mileage by age cumulatively. Table 2-1 lists mileage accumulation by age calculated from the most current data available (1979). Since the data presented were collected from rural and urban areas, the figures provided in Table 2-1 apply to both urban and rural vehicles. Thus, if urban estimates are available from local agencies, they can be used in place of those provided in Table 2-1. Travel patterns may change, therefore, updated information should be used when it becomes available.

2.1.3 Problems Associated with the Estimation Technique

If the MOBILE2 user utilizes the data presented in Table 2-1, a bias will probably be introduced into the mileage accumulation by age estimates. This is because Table 2-1 presents data based on national

TABLE 2-1

ESTIMATED ANNUAL MILES TRAVELED AND
MILEAGE ACCUMULATION BY AGE
FOR LIGHT-DUTY VEHICLES

Age	Estimated Annual Miles	Accumulated Miles
1	14,436	14,436
2	13,903	28,339
3	13,371	41,710
4	12,838	54,548
5	12,306	66,854
6	11,773	78,627
7	11,240	89,867
8	10,708	100,575
9	10,176	110,751
10	9,643	120,394
11	9,110	129,504
12	8,577	138,081
13	8,045	146,126
14	7,513	153,639
15	6,980	160,619
16	6,447	167,066
17	5,927	172,993
18	5,382	178,375
19	4,850	183,225
20	4,317	187,542

Source: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1980.

averages and driving patterns will vary between states and localities. It is not anticipated that the national estimates of mileage accumulation by age should be significantly different than local estimates, hence they should be used if local estimates are not available. This technique is one of the simplest since all the data can be obtained from one source, and only a simple addition is required -- adding annual miles by age cumulatively.

2.2 LIGHT AND HEAVY-DUTY TRUCKS

The following sections describe the data sources and steps required to estimate mileage accumulation by age for five classifications of trucks. A section defining problems associated with this method is also included.

2.2.1 Data Sources

To estimate mileage accumulation by age, average first year mileages must be estimated as well as the reduction in miles traveled due to aging. The estimates of average first year mileages and the reduction in miles for each truck class are listed in Section 2.2.2. The source of these data is The Development of an Emission and Fuel Economy Computer Model for Heavy-Duty Trucks and Buses, by Jambekar and Johnson, August 1977. This source utilized the 1972 Bureau of the Census, Truck Inventory and Use Survey (TIUS) nationwide report. The data presented in this report can be updated by using the Public Use Tape for the 1977 TIUS report. This tape includes truck characteristic data for a sample of trucks registered in the United States. The cost of this tape, however, is $80. If the user decides to use the 1977 TIUS data, individual state data should be used instead of national data, so that truck mileage accumulation by age for a locality can be more accurately estimated (mileage accumulation by age varies from the national averages by state and locality). It should be noted that some agencies within states and localities collect data on mileage accumulation by age for

the various truck classifications. For instance, the Southern California Association of Governments (SCAG) compiles data on mileage accumulation by age for four truck classifications. The Atlanta Regional Council collects mileage data for trucks, and classifies the trucks by number of axles. This classification can be restructured into the truck classifications listed below. Thus, similar agencies in the state or locality of interest should be contacted to determine whether mileage accumulation by age data for the truck classifications listed below are available locally or statewide before national estimates are used or the estimation procedure listed in Section 2.2.2 is implemented.

The truck classes for the purpose of this study are defined as follows:

LDGT1: Light duty gas truck (<6001 lbs GVW)
LDGT2: Light duty gas truck (>6000 lbs and <8501 lbs GVW)
HDGV : Heavy duty gas truck (>8500 lbs GVW)
LDDT : Light duty diesel truck (<8500 lbs)
HDDV : Heavy duty diesel truck (>8500 lbs)

2.2.2 Procedure for Estimation

Included in this section are estimates of mileage accumulations for each class of truck and estimates of the intermediary numbers needed to calculate the accumulations. However, these figures are based on 1972 data. Thus, the MOBILE2 user may wish to update the data provided herein. Hence, the estimation technique that was utilized to arrive at these estimates is described in detail so that mileage accumulation updating may be performed if desired.

The Truck Inventory and Use Survey (TIUS) Public Use Tape does not specifically report first year mileage, but this can be easily calculated. Total annual miles are reported in the TIUS tape; and if a vehicle is owned for less than 12 months, the yearly miles are estimated

and reported. Therefore, average first year mileages per truck classification can be calculated by using the average yearly mileages for all trucks (by classification) which are reported to be 0-12 months old (based on model year 1977). If other local data sources are available, they can be used instead of the TIUS data.

Once average first year mileages are estimated for each truck classification, the reduction in mileage due to age must be calculated so that mileage accumulation by age can be approximated. The Truck Inventory and Use Survey Public Use Tape reports total miles traveled (as read from odometers) by vehicle type by model year. By using these data, "fraction reduction curves", reduction in mileage due to age, can be generated for each truck classification. These curves can be generated by graphically plotting fractional change in first year mileage by vehicle age and fitting a curve through the points. The fractional mileage reductions can be calculated as follows:

$$FR_a = \frac{\text{First year mileage} - \text{annual mileage of vehicle}_{MY}}{\text{First year mileage}} \qquad (2\text{-}1)$$

where: a = age of vehicle (current year - model year)

MY = model year of the vehicle

An example illustrating equation (2-1) using 1977 as the current year (year 0-1) is as follows:

Age	Model Year	Average Annual Miles per Truck
0-1	1977	19,500 (1st yr mileage)
2	1976	17,400
3	1975	16,000

$$FR_2 = \frac{19{,}500 - 17{,}400}{19{,}500} = .108$$

$$FR_3 = \frac{19,500 - 16,000}{19,500} = .179$$

Since the most current TIUS data available are 1977 data, the current year is 1977. It is assumed that reductions in mileage due to age will not vary with the introduction of newer cars (i.e., 1980). Hence, the fraction reductions can be used for predicting mileage accumulation by age using other year's first year mileages as the base year.

Tables 2-2 and 2-3 list first year mileages and fraction reduction estimates according to vehicle classifications which were taken from the Jambekar and Johnson report. Jambekar and Johnson extracted these data from the Census of Transportation, 1972 Truck Inventory and Use Survey national report. It should be noted that the fraction reduction estimates for the LDGT1 and LDGT2 categories are the same. These data can be used in lieu of generating data from the 1977 Census report; however, care should be exercised in using these data since 1972 was a pre-embargo (before travel characteristics were influenced by fuel prices) year and travel characteristics could have changed considerably in the meantime.

The mileage accumulation by age figures were calculated from the information listed in Tables 2-2 and 2-3 -- first year mileage and the fraction reduction curves. For example, using the 1972 data in Tables 2-2 and 2-3, the mileage accumulation of a 7 year old light-duty gas truck (0-6000 lbs GVW) is equal to 15610*(1 + .9 + .8 +.72 + .65 + .60 + .55) = 81,484 miles. Therefore, the general formula for mileage accumulation by age is:

$$\text{Mileage Accumulation by Age} = FYM_t \sum_{i=1}^{a} (1 - FR_{it}) \qquad (2\text{-}2)$$

TABLE 2-2

FIRST YEAR MILEAGES PER VEHICLE TYPE

Gasoline Classes	First Year Mileage
LDGT1 (0-6000 lbs)	15,610
LDGT2 (6001-8500 lbs)	15,800
*HDGV (>8500 lbs)	18,619
Diesel Classes	
LDDT (<8500 lbs)	15,705
*HDDV (>8500 lbs)	70,418

* The first year mileages in these categories are the weighted first year mileages of the six GVW categories. Since the figures are from 1972 data, they are weighted by the 1972 factory sales data as extracted from the Jambekar and Johnson report.

Source: Jambekar and Johnson, 1977.

TABLE 2-3

FRACTIONAL REDUCTION IN MILES TRAVELED DUE TO AGE

		Gasoline Class			Diesel Class	
	Age	LDGT1	LDGT2	HDGV*	LDDT	HDDV*
(First Year)	0-1	0.0	0.0	0.0	0.0	0.0
	2	.10	.10	.10	.04	.05
	3	.20	.20	.18	.07	.14
	4	.28	.28	.26	.11	.23
	5	.35	.35	.33	.17	.32
	6	.40	.40	.40	.23	.38
	7	.45	.45	.46	.30	.44
	8	.49	.49	.51	.38	.48
	9	.52	.52	.55	.50	.51
	10	.55	.55	.59	.57	.54
	11	.58	.58	.62	.57	.54
	12	.60	.60	.65	.61	.55
	13	.62	.62	.68	.65	.56
	14	.65	.65	.70	.68	.58
	15	.67	.67	.72	.71	.61
	16	.68	.68	.74	.73	.65
	17	.70	.70	.75	.76	.71
	18	.72	.72	.76	.80	.75
	19	.72	.72	.76	.80	.75
	20 & above	.72	.72	.76	.80	.75

Source: Jambekar and Johnson, 1977

* The fraction reductions in these classes are the weighted average of the fraction reductions for six GVW categories. They are weighted by factory sales in each category.

where: FYM = first year mileage (e.g., see Table 2-2)

FR_{it} = fraction reduction for a vehicle i years old of type t (e.g., see Table 2-3)

a = age of the vehicle

t = vehicle type (by GVW)

In the 20 year category, the average accumulation of all vehicles 20 years of age or older was calculated using equation (2-2) and assuming a maximum life of 30 years. It is reasonable to assume that total mileage accumulation by age does not vary significantly between national and regional/local vehicles. For instance, the average mileage accumulation for vehicles registered in a state (as recorded in the Census of Transportation) should be representative of the mileage accumulation of a vehicle registered in a specific locality within the state. This assumption can be changed if a user of MOBILE2 in a locality has access to mileage accumulation data for that locality or has access to data which can be utilized to calculate fraction reduction factors which can be applied to apportion the mileage accumulation figures.

Table 2-4 lists mileage accumulations by age for each of the truck categories. Since the original source of these data was the TIUS, and the TIUS is based on surveys taken from both rural and urban areas, these estimates are not specific to urban areas only. These data were tabulated from Tables 2-2 and 2-3 and can be used in MOBILE2 if state/local data are not available and if updating is not desired.

2.2.3 Possible Problems Associated with the Estimation Technique

The assumption that national accumulated mileage is equal to local accumulated mileage may introduce error in the variable estimate. Trucks operating solely in an urban area for non-commercial use could conceivably accrue less mileage than trucks which are used for long distance and urban travel. In contrast, many trucks registered in an

TABLE 2-4

MILEAGE ACCUMULATION BY AGE

Age	LDGT1	LDGT2	HDGV	LDDT	HDDV
1	15,610	15,800	20,980	15,705	70,418
2	29,659	30,020	39,862	30,782	137,315
3	42,147	42,660	57,066	45,387	197,875
4	53,386	54,036	72,591	59,365	252,096
5	63,533	64,306	86,648	72,400	299,981
6	72,899	73,786	99,235	84,493	343,640
7	81,484	82,476	110,564	95,486	383,074
8	89,445	90,534	120,844	105,224	419,692
9	96,938	98,118	130,285	113,077	454,196
10	103,963	104,754	138,887	119,830	486,589
11	110,519	111,390	146,860	126,583	518,981
12	116,763	117,710	154,203	132,708	550,669
13	122,695	123,714	160,916	138,205	581,653
14	128,158	129,224	167,210	143,230	611,229
15	133,309	134,458	173,085	147,785	638,692
16	138,305	139,514	178,539	152,025	663,338
17	142,988	144,254	183,784	155,794	683,759
18	147,358	148,678	188,820	158,935	701,364
19	151,729	153,102	193,854	162,076	718,968
20 and above	177,954	179,646	208,960	180,922	798,189

Source: Jambekar and Johnson, 1977.

urban area may be used mostly for long distance trips and may accrue mileage more quickly than the above method would estimate. In addition, the local mix of truck size distributions in a particular class may be different than the national mix upon which average first year mileages and fraction reductions are estimated. As mentioned above, these type of errors cannot be corrected for unless local data on truck characteristics are available. The extra effort required to localize the data may not be worthwhile since the trucks accruing less mileage or greater mileage than national estimates will probably, on the average, be near the estimates of national mileage accumulated by age. Thus, as long as the MOBILE2 user is aware of the potential problems associated with the national estimates, the national estimates should be used, unless mileage accumulation estimates on a local level are readily available.

Travel characteristics are constantly changing since gasoline prices are still rising and travel has become more expensive. Therefore, the fraction reduction curves based on 1972 and even 1977 data, may add some error into the estimation of mileage accumulation by age. These curves should be updated as often as possible, though the updating would require extra time and money. The steps required to estimate mileage accumulation by age are far more tedious than difficult, and thus this method should not be unduly difficult to implement.

2.3 MOTORCYCLES

The following sections discuss the data sources required, the estimation procedure and problems associated with estimating motorcycle mileage accumulation by age.

2.3.1 Data Sources

The Motorcycle Industry Council (MIC) asked Human Factors Research, Inc. to reanalyze the mileage accumulation information in the Gallup Organization's Survey of Motorcycle Ownership, Usage and Maintenance report.

Hence, the data herein are revised from the data appearing in that report. The revised data were obtained via conversations with the MIC.

2.3.2 Estimation Technique

Table 2-5 lists motorcycle average miles traveled per year by age and mileage accumulation by age for registered motorcycles (on-road and dual purpose motorcycles are registered for use on public roads). These figures are based on national mileage estimates and on the assumption that motorcycles are driven an average of 7 months per year nationwide. Table 2-6 relaxes this assumption and lists mileage accumulations for varied driving season lengths. Table 2-7 lists average driving season lengths for eight regions within the U.S. and the states in these regions. Thus, to calculate mileage accumulation by age for motorcycles for a particular locality, the MOBILE2 user should choose the appropriate driving season length from Table 2-7 for their state, and use the mileage accumulation figures from Table 2-6 which correspond to that driving season length. This method assumes that the national mileage accumulation averages are valid for individual communities. Table 2-7 lists both mean number of months and median number of months by region that motorcycles are driven. These are averages; therefore if a user of MOBILE2 has information on the length of the motorcycle driving season (in months) for the particular locality, the mileage accumulation for that driving season length should be used rather than the average regional driving season. Potential sources of local/state information on driving season lengths and motorcycle mileage accumulation by age are Councils of Government, State Departments of Transportation, and State Departments. The data provided in this section are basically urban area estimates since the mileage accumulation data on off-road motorcycles has not been utilized (off-road motorcycles are assumed to be used in rural areas only).

TABLE 2-5

AVERAGE MILES PER YEAR BY AGE AND MILEAGE ACCUMULATION BY AGE FOR MOTORCYCLES

Age	Average Miles* Per Year	Average Mileage Accumulation
1	4067	4067
2	2845	6912
3	2072	8984
4	1569	10553
5	1180	11733
6	777	12510
7	630	13140
8	387	13527
9	243	13770
10	162	13932
11	162	14094
12	162	14256
13	162	14418
Mean number of months per year	7	
Median number of months per year	7	7

* Weighted by the mix of on-road and dual purpose motorcycles registered in 1978.

Source: Personal Communication with Pam Amette, Motorcycle Industry Council, Inc., and the 1979 Motorcycle Statistical Annual

TABLE 2-6

AVERAGE ANNUAL MILEAGE AND MILEAGE ACCUMULATION BY AGE BY AVERAGE MONTHS OF USE

		NUMBER OF MONTHS											
		5		6		8		9		10		11		12	
AGE	Avg. Annual Mileage	Mileage Accum.	Avg. Annual Mileage	Mileage Accum.	Avg. Annual Mileage	Mileage Accum.	Avg. Annual Mileage	Mileage Accum.	Avg. Annual Mileage	Mileage Accum.	Avg. Annual Mileage	Mileage Accum.	Avg. Annual Mileage	Mileage Accum.
0- 1	2905	2905	3486	3486	4648	4648	5229	5229	5810	5810	6391	6391	6972	6972
1- 2	2032	4937	2439	5925	3251	7899	3658	8887	4064	9874	4470	10861	4877	11849
2- 3	1480	6417	1776	7701	2368	10267	2664	11551	2960	12834	3256	14117	3552	15401
3- 4	1121	7538	1345	9046	1793	12060	2017	13568	2241	15075	2466	16583	2690	18091
4- 5	843	8381	1011	10057	1349	13409	1517	15085	1686	16761	1854	18437	2023	20114
5- 6	555	8936	666	10723	888	14297	999	16084	1110	17871	1221	19658	1332	21446
6- 7	450	9386	540	11263	720	15017	810	16894	900	18771	990	20648	1080	22526
7- 8	276	9662	332	11595	442	15459	496	17390	553	19324	608	21256	663	23189
8- 9	174	9836	208	11803	278	15737	312	17702	347	19671	382	21638	417	23606
9-10	116	9952	139	11942	185	15922	208	17910	231	19902	255	21893	278	23884
10-11	116	10068	139	12081	185	16107	208	18118	231	20133	255	22148	278	24162
11-12	116	10184	139	12220	185	16292	208	18326	231	20364	255	22403	278	24440
12-13	116	10300	139	12359	185	16477	208	18534	231	20595	255	22658	278	24718

TABLE 2-7

DRIVING SEASON LENGTH IN MONTHS PER U.S. REGION

	New England	Mid Atlantic	E. Central	W. Central	South-West	South-East	Rocky Mountain	Pacific
	Maine New Hampshire Vermont Massachusetts Rhode Island Connecticut	New York New Jersey Pennsylvania	Ohio Indiana Illinois Michigan Wisconsin	Minnesota Iowa Missouri N. Dakota S. Dakota Nebraska Kansas Arkansas Louisiana Oklahoma Texas	Kentucky Tennessee Alabama Mississippi	Delaware Maryland D.C. Virginia W. Virginia N. Carolina S. Carolina Georgia Florida	Montana Idaho Wyoming Colorado N. Mexico Arizona Utah Nevada	Washington Oregon California Alaska Hawaii
Median Driving Season	7	6	6	6	12	12	7	6
Mean Driving Season	6	6	5	6	8	9	7	6

Source: Motorcycle Industry Council, Inc. Survey of Motorcycle Ownership, Usage, and Maintenance, conducted by the Gallup Organization, Inc., 1975

If the user does not have access to specific information on motorcycle driving season lengths, then the data in Table 2-7 must be utilized and the distinction between the mean and median driving season length must be realized. The calculation of the mean length includes all the sample data points, however, extreme values can influence the mean and make its value less representative of the sample points. The calculation of the median, on the other hand, does not take the individual sample point values into account, since it is a positional measure. (The values are ranked in ascending order and the number in the center position -- that which divides the number of data points in half is the median value.) The median is not as affected as the mean by extreme values, but it may be nonrepresentative if the individual points do not tend to cluster at the center of the distribution. Since the mean and the median measures of central tendency have drawbacks, the user of MOBILE2 can use both measures to obtain a range of estimates.

2.3.3 Possible Problems Associated with the Estimation Technique

The methodology explained above is based solely on national and regional travel data. The data presented are averages of various locality data. Therefore, as mentioned in the above section, the mileage accumulation figures for a specific locality will vary from the national and regional estimates as will the average motorcycle season lengths. For instance, motorcycle use in an urban area in southern Florida is typically year-round, where use in an urban area in West Virginia, a state which is in the same region as Florida, will most likely be less than 12 months. Thus, the mean number of months of travel in the South-East region is 9 months and the median number is 12 months.

Since motorcycle usage varies within the eight U.S. regions and also within individual states, it is recommended that usage data on a local level be used if available. If the estimates listed in Tables 2-5 and 2-6 must be used, however, the user of MOBILE2 should be aware of the

biases that may result. The estimates of mileage accumulation may be higher or lower than actuality, the degree of error depending on many factors such as weather, distribution of wealth within an urban area, (i.e., whether the motorcycle is the only vehicle owned, or if the owner uses the motorcycle for pleasure only) and the distribution of motorcycle types within the area (i.e., on-street, dual purpose). If the MOBILE2 user suspects that the estimates being used are too low or too high, the model should be run using a range of estimates and sensitivity analyses should be performed.

The level of effort associated with this technique should be minimal unless the user feels that it is necessary to perform sensitivity analyses on emissions by using variations in the mileage accumulation figures and average season length data.

REFERENCES FOR SECTION 2

Jambekar, A. and Johnson, J. 1977. The Development of an Emission and Fuel Economy Computer Model for Heavy-Duty Trucks and Buses. Michigan Technological University. Houghton, MI.

Motorcycle Industry Council, Inc. 1979. Motorcycle Statistical Annual. Newport Beach, CA.

The Gallup Organization, Inc. January 1975. Survey of Motorcycle Ownership, Usage and Maintenance. Conducted for the Motorcycle Industry Council, Inc. Newport Beach, CA.

U.S. Department of Commerce. 1972. Truck Inventory and Use Survey. Census of Transportation. Bureau of the Census. Washington, DC.

U.S. Department of Transportation. April 1972. Nationwide Personal Transportation Study. Report Nos. 1-11. Federal Highway Administration. Washington, DC.

U.S. Department of Transportation. March 31, 1980. Letter from Barry Felrice to Michael P. Walsh. (U.S. EPA-Mobile Source Air Pollution Control). National Highway Traffic Safety Administration. Washington, DC.

3. VEHICLE REGISTRATIONS BY AGE

Once data on mileage accumulation by age by vehicle type are compiled, it is necessary to estimate the number of vehicles in each age and type category to predict the mix of mobile source emissions in a given area. The following sections identify methods for estimating vehicle registration fractions by age. The methods for light-duty vehicles, five truck classes, and motorcycles differ. Therefore, the methods are described separately for each vehicle type. The techniques described below are not considered to be "better" than any other estimation technique. Hence, this section simply presents alternative methods available to estimate vehicle registration fractions by age.

It should be noted that annual vehicle registration procedures vary between states. For example, nine states use the calendar year for registering all vehicles, ten states for trucks only and one state for automobiles only. Thirty-two states register their automobiles on a "staggered" basis, and seven states register all of their vehicles in this manner. Four states register all of their vehicles in March or April, three states use these months to register automobiles only, and seven states register trucks only during March or April. The remaining states use other dates from the middle to the latter part of the year. Most states allow preregistrations or permit "grace periods" to better distribute the annual registration workload (U.S. DOT, 1978). Therefore, the registration data contained in the following sections for all types of motor vehicles may contain inconsistencies. Most of the sources cited attempt to present the data uniformly for all states (and aggregated for the nationwide statistics), but some inconsistencies may still result.

3.1 LIGHT-DUTY VEHICLES-- METHOD 1

The subsequent sub-sections identify the data sources, the estimation techniques and the assumptions and problems associated with these techniques, when used to estimate light-duty gasoline and diesel vehicle registration fractions by age from nationwide data. This method uses the number of vehicles registered (nationwide) by age to calculate the registration fractions for each year.

3.1.1 Data Sources

The primary data sources needed to estimate light-duty vehicle registration fractions by age are the Motor Vehicle Manufacturers Association (MVMA, 1979) annual report, and the Automotive News, 1979 Market Data Book Issue. These reports include national registration by age data for years up to and including 1978. In addition, data from an SAE technical paper entitled "Factors Influencing Automotive Fuel Demand" (McNutt, Dulla, and Lax, 1979) were used to apportion domestic and import registration by fuel type. Since the mix of light-duty gasoline and diesel vehicles is expected to change considerably within the next decade, it is advisable to account for this change periodically, if possible.

There are potential sources of light-duty vehicle registration by age data available on a state/local level and these should be used where possible. For instance, the Southern California Association of Governments (SCAG) compiles information on the age distributions of light-duty vehicles registered in the Los Angeles area. The Ohio Transportation and Development Planning Program uses local vehicle age mixes supplied by R.L. Polk. Both the Michigan Department of State and the Chicago Secretary of State compile data on vehicle registrations by age. Similar data have been compiled in the past by the Philadelphia Regional Planning Commission and the Atlanta Regional Council. Therefore, MOBILE2 users should contact similar agencies in their area to determine if local

registration by age data are available. If the data are available locally, they should be used in lieu of the techniques described herein.

3.1.2 Estimation Technique

Table 3-1 shows the distribution of total, domestic and import light-duty vehicle registrations by age calculated from nationwide data. This table also includes the percentage of the light-duty vehicle fleet in each year that were diesel and gasoline-powered for both domestic and import light-duty vehicles (McNutt, Dulla, and Lax, 1979). Thus, to calculate total diesel registrations by age, these percentages should be multiplied by the domestic (import) LDV registrations for each age category. The sum of the products for each age category resulting from this calculation should estimate LDGV and LDDV by age. It follows that total registrations by age minus diesel registrations by age is equal to total light-duty gas vehicle registrations by age. Table 3-1 shows the calculations required to estimate LDGV and LDDV registrations by age. Table 3-2 lists the results of these calculations and the associated LDGV and LDDV registration fractions by age. Assuming the nationwide age distribution is relatively constant across state and local areas, light-duty vehicle registration fractions by age can be taken directly from Table 3-2. Since the sources utilized to calculate these estimates are based on both urban and rural data, the estimation technique described above applies to both urban and rural areas.

3.1.3 Problems Associated with the Estimation Technique

The above method assumes that the national distribution of vehicles registered by age is the same as the distribution in specific localities. This assumption could be in error. Most errors would tend to produce a higher percentage of registrations in older age categories than the actual urban area distributions. This could result because many urban areas are areas of high commerce, with higher than average

TABLE 3-1

LIGHT-DUTY VEHICLE REGISTRATIONS BY AGE OF VEHICLE
(as of July 1)

Base Year 1978 (1978 = Age 1)

Age by Model Year Mix	(1)** Total Registrations	(2) (1)-(5) Domestic	(3)* Percentage Domestic Diesel	(4) Domestic Diesel (2)x(3)	(5)+ Import	(6)* Percentage Import Diesel	(7) Import Diesel (5)x(6)	(8) Total Diesel (4)+(7)	(9) Total Gas (1)-(8)
1	7426000	5412019	0.5	27,060	2013981	2.6	52364	79424	7346576
2	10382000	8316308	0.5	41,582	2065692	1.9	39248	80830	10301170
3	9483000	7988275	0.0	0	1491725	1.3	19392	19392	9463608
4	7291000	5805175	0.0	0	1485825	1.0	14858	14858	7276142
5	9431000	8104938	0.0	0	1326062	0.8	10608	10608	9420392
6	10559000	8945345	0.0	0	1613655	0.5	8068	8068	10550932
7	9140000	7807374	0.0	0	1332626	0.4	5330	5330	9134670
8	7326000	5932828	0.0	0	1393172	0.3	4180	4180	7321820
9	6784000	5650309	0.0	0	1133691	0.4	4535	4535	6779465
10	6087000	6087000	0.0	0		0.0	0	0	6087000
11	4917000	4917000	0.0	0		0.0	0	0	4917000
12	3589000	3589000	0.0	0		0.0	0	0	3589000
13	3093000	3093000	0.0	0		0.0	0	0	3093000
14	2369000	2369000	0.0	0		0.0	0	0	2369000
15	1545000	1545000	0.0	0		0.0	0	0	1545000
16	1021000	1021000	0.0	0		0.0	0	0	1021000
17	571000++	620000	0.0	0		0.0	0	0	571000
18	256000	530000	0.0	0		0.0	0	0	256000
19	180000	515000	0.0	0		0.0	0	0	180000
20+	1489000	831000	0.0	0		0.0	0	0	1489000
TOTAL	102939000							227225	102711775

* Source: McNutt, Dulla, and Lax, 1979.

**Source: MVMA, Motor Vehicle Facts and Figures 1979

+ Source: Automotive News Market Data Book Issue (various years)

++Source: The MVMA Motor Vehicle Facts and Figures 1979 report only provides yearly registration data for the 16 most recent model years. Therefore, the total registrations for model years 17-20 were estimated using the scrappage rates in Table 3-3 and registrations in year 16 for those model years.

TABLE 3-2

LIGHT-DUTY VEHICLE REGISTRATIONS BY AGE BY TYPE
(1978)

AGE	Light-Duty Gas Vehicles		Light-Duty Diesel Vehicles	
	Number of Vehicle Registrations	Percentage* of Total LDGV Registrations	Number of Vehicle Registrations	Percentage* of Total LDDV Registrations
1	7346576	.0715	79424	.3495
2	10301170	.1003	80830	.3557
3	9463608	.0921	19392	.0853
4	7276142	.0708	14858	.0654
5	9420392	.0917	10608	.0467
6	10550932	.1027	8068	.0335
7	9134670	.0889	5330	.0235
8	7321820	.0713	4180	.0184
9	6779465	.0660	4535	.0200
10	6087000	.0592	--	--
11	4917000	.0479	--	--
12	3589000	.0349	--	--
13	3093000	.0301	--	--
14	2369000	.0231	--	--
15	1545000	.0150	--	--
16	1021000	.0100	--	--
17	571000	.0056	--	--
18	256000	.0025	--	--
19	180000	.0018	--	--
20+	1489000	.0145	--	--
TOTAL	102711775	1.0000	227225	1.0000

*May not equal 1.00 because of rounding.

Source: MVMA, Motor Vehicle Facts and Figures 1979
Automotive News, Market Data Book Issue (various years)

employment and income levels. Thus, newer cars are probably more prevalent in urban areas. Also, cars last longer where roads are not salted and where there is no salt in the air.

On the other hand, persons driving in very densely populated and conjested urban areas will probably decide to fix their older vehicles rather than replace their vehicles every few years since these areas are harsher on the appearance and engine of the car. Thus the incentive to buy a new car could be depressed in this type of area. This would tend to make the national distribution appear to have a higher percentage of registrations in newer age categories than the actual urban area distribution.

The diesel penetration figures are estimates and could bias the light-duty diesel registration by age estimates somewhat. However, because they are based on historical data the bias should not be significant. The estimation technique described above should not be difficult to carry out since the data are readily available and only simple mathematical processes need to be used; thus, the method described above is, at most, tedious.

3.2 LIGHT-DUTY VEHICLES -- METHOD 2

The following sections describe an alternative to the method described in Section 3.1 for estimating light-duty gasoline and diesel-powered vehicle registrations by age from national data. The subsequent sections will discuss the data sources required, the estimation technique and the problems associated with it. This method utilizes sales data (local, if possible) along with nationwide scrappage rates to estimate registrations. If local registration data are available, this technique should not be used. This method, unlike method 1, can more easily track the yearly differences in registrations by age since yearly sales data are applied to constant scrappage rates.

3.2.1 Data Sources

The 1979 Wards Automotive Yearbook lists total, domestic and import light-duty vehicle new car registrations and sales for the years 1955 through 1978. Diesel penetration data from an SAE technical paper (McNutt, Dulla and Lax, 1979) can be used to apportion these sales by fuel type. These data along with data on scrappage rates from the National Highway Traffic Safety Administration (or other reliable sources on scrappage rates) can be used to estimate nationwide light-duty vehicle registrations by age. To the extent that the gasoline/diesel sales mix is changing, updated sales data should be used with new diesel/gasoline penetration fractions to reflect the changing trends. As mentioned in Section 3.1.1, various local/state sources of light-duty vehicle registration by age data are available. When available, these should be used in lieu of the technique described here.

3.2.2 Estimation Technique

The number of light-duty vehicles of a particular model year registered in a calendar year depends on the number of light-duty vehicles originally sold by model year and assumed to be registered, and the number of those originally sold that are "scrapped" due to attrition. Table 3-3 lists scrappage rates calculated by the National Highway Traffic Safety Administration from R.L. Polk, July 1977 and 1978 registration data. It is assumed that these rates apply equally to gas and diesel light-duty vehicles. These rates are one of many estimates; if scrappage rate data for specific localities are available, they should be used instead of those presented in Table 3-3. Vehicle ownership trends are changing as smaller, fuel efficient light-duty vehicles increase their market share; therefore, the scrappage rates should be updated frequently. If reliable sources of recent scrappage rates are not available, or if it is evident that LDGVs are scrapped at a different rate than LDDVs, they can be easily calculated using the following equation:

TABLE 3-3

SCRAPPAGE RATES BY AGE FOR LIGHT-DUTY VEHICLES

AGE	Scrappage Rate
1	000
2	.008
3	.032
4	.049
5	.075
6	.116
7	.176
8	.250
9	.344
10	.450
11	.553
12	.644
13	.721
14	.781
15	.830
16	.881
17	.917
18	.942
19	.959
20+	.980

Source: National Highway Traffic Safety Administration, 1980.

$$SR_{a,f} = \frac{S_{MY,f} - Stk_{MY,i,f}}{S_{MY,f}} \qquad (3\text{-}1)$$

where: $S_{MY,f}$ = sales of a light-duty vehicle of model year MY, fuel f

$Stk_{MY,i,f}$ = stock (registrations) remaining of the light-duty vehicle in year i, fuel f

a = age of vehicle (i - MY)

f = gas or diesel

To calculate nationwide scrappage rates, light-duty vehicle new car registration data can be extracted from the Wards Automotive Yearbook and stock data (registrations of model year MY in year i) can be extracted from the MVMA Motor Vehicle Facts and Figures annual. Points for each age should be calculated and a line should be fit (using regression analyses) through these points. The individual scrappage rates for each age (0-20) can then be determined from the line. Once scrappage rates are tabulated or collected, sales data need only be collected for each current year to update the fractions of registrations by age yearly.

Table 3-4 lists nationwide light-duty vehicle new domestic and import new car registration data for 1978 through 1958 (20 years). This table also calculates new vehicle sales by fuel type using diesel penetrations, using the methodology described in Section 3.1.2. Table 3-5 lists light-duty gas vehicle and light-duty diesel sales by MY as calculated from the data presented in Table 3-4. Light-duty vehicle registrations by fuel type by age can be calculated using this information and the scrappage rate data from Table 3-3. The following equation can be used to calculate registrations by age by type:

$$LDVR_{a,f} = S_{MY,f} (1 - SR_a) \qquad (3\text{-}2)$$

where: $LDVR_{a,f}$ = light-duty vehicle registrations of age a, fuel f

$S_{MY,f}$ = sales of LDV of model year MY, fuel f

TABLE 3-4

DOMESTIC AND IMPORT NEW LIGHT DUTY VEHICLE REGISTRATIONS BY MODEL YEAR BY FUEL TYPE

	D O M E S T I C				I M P O R T			
	(1) Total New Registrations	(2) Percentage* Diesel	(3) Diesel New Registrations (1)-(3)	(4) Gasoline New Registrations (1)-(3)	(5) Total New Registrations	(6) Percentage* Diesel	(7) Diesel New Registrations (5)x(6)	(8) Gasoline New Registrations (5)-(7)
1978	9000000	.5	45000	8955000	1946104	2.6	50599	1895505
1977	8849722	.5	44249	8805473	1976512	1.9	37554	1938958
1976	8304848			8304848	1446637	1.3	18806	1427831
1975	6760912			6760912	1500928	1.0	15009	1485919
1974	7331946			7331946	1369148	.8	10953	1358195
1973	9631082			9631082	1719913	.5	8600	1711313
1972	8958392			8958392	1529402	.4	6118	1523284
1971	8343013			8343013	1487613	.3	4463	1483150
1970	7157243			7157243	1230961	.4	4924	1226037
1969	8384907			8384907	1061617			1061617
1968	8418095			8418095	985767			985767
1967	7578201			7578201	779220			779220
1066	8350365			8350365	658123			658123
1965	8744497			8744497	569415			569415
1964	7581019			7581019	484131			484131
1963	7171093			7171093	385624			385624
1962	6599703			6599703	339160			339160
1961	5476125			5476125	378622			378622
1960	6077865			6077865	498785			498785
1959 and below	28853000**			28853000	1356100			1356100

* McNutt, Dulla, and Lax, 1979.

** Sum of 1955-1959 new import car registrations.

Source: 1979 Wards Automotive Yearbook

TABLE 3-5

NEW LIGHT DUTY VEHICLE GASOLINE AND DIESEL
REGISTRATIONS BY MODEL YEAR

Model Year	Gas	Diesel	TOTAL
1978	10,805,505	95,599	10,946,104
1977	10,744,431	81,803	10,826,234
1976	9,732,679	18,806	9,751,485
1975	8,246,831	15,009	8,261,840
1974	8,690,141	10,953	8,701,094
1973	11,342,395	8,600	11,350,995
1972	10,481,676	6,118	10,487,794
1971	9,826,163	4,463	9,830,626
1970	8,383,280	4,924	8,388,204
1969	9,446,524		9,446,524
1968	9,403,862		9,403,862
1967	8,357,421		8,357,421
1966	9,008,488		9,008,488
1965	9,313,912		9,313,912
1964	8,065,150		8,065,150
1963	7,556,717		7,556,717
1962	6,938,863		6,938,863
1961	5,854,747		5,854,747
1960	6,576,650		6,576,650
1959	30,209,100*		30,209,100

Source: 1979 Wards Automotive Yearbook.

*Sum of 1955 to 1959 new import car registrations.

SR_a = scrappage rate of an LDV of age a

a = age of LDV (current year - MY)

f = fuel = gas or diesel

If local sales data are available, they should be used in lieu of the information in Table 3-4. Whatever sales data are used, equation (3-2) should be applied to estimate registrations by age. Then, registration fractions by vehicle age can be calculated. An example of this method using nationwide data is shown in Table 3-6. It should be noted that since the sales data available do not distinguish between rural and urban sales, the estimation technique can be used for either rural or urban registration fractions by age.

3.2.3 Problems Associated with the Estimation Technique

It is assumed in the above technique that nationally derived scrappage rates apply to all areas. This assumption will probably bias the registration estimates, since light-duty vehicles in an urban area typically have shorter life-spans than light-duty vehicles used in non-urban areas. Alternatively, as mentioned in Section 3.1.3, automobile owners using their vehicles in densely populated and congested areas may decide to fix their old vehicles in lieu of replacing them since vehicles in these areas generally face harsher driving conditions than non-congested areas and are involved in small accidents more frequently. Hence, if data can be gathered on scrappage for local areas, these should be used instead of the data listed in Table 3-3.

The market share estimates used in Section 3.1.2 to calculate diesel and gas registrations are also used here to calculate diesel and gas sales. However, as mentioned in Section 3.1.3, the resulting biases should not be very large in magnitude. If sales data are available by fuel type for states or localities, these should be used in lieu of the estimates presented in Table 3-4.

TABLE 3-6

SAMPLE CALCULATION OF LIGHT DUTY
GAS VEHICLE REGISTRATIONS BY MODEL YEAR

Model Year	Scrappage Rates* (from Table 3-3) (1-SR)	Nationwide Sales (from Table 3-5)	Estimated Registrations	Registration Fractions
1978	1.000	10,805,505	10,805,505	.109
1977	.992	10,744,431	10,658,476	.107
1976	.968	9,732,679	9,421,233	.095
1975	.951	8,246,831	7,842,736	.079
1974	.925	8,690,141	8,038,380	.081
1973	.884	11,342,395	10,026,677	.101
1972	.824	10,481,676	8,636,901	.087
1971	.750	9,826,163	7,369,622	.074
1970	.656	8,388,280	5,499,432	.055
1969	.550	9,446,524	5,195,588	.052
1968	.447	9,403,862	4,203,526	.042
1967	.356	8,357,421	2,975,242	.030
1966	.279	9,008,488	2,513,368	.025
1965	.219	9,313,912	2,039,747	.021
1964	.170	8,065,150	1,371,076	.014
1963	.119	7,556,717	899,249	.009
1962	.083	6,938,863	575,926	.006
1961	.058	5,854,747	339,575	.003
1960	.041	6,576,650	269,643	.003
1959	.020	30,209,100**	604,182	.006
			99,286,128	1.000

*Percentage remaining in vehicle fleet.

**Sum of 1955-1959 New import car registrations.

If reliable current scrappage rates are available, estimating light-duty vehicle registrations by age using the method described in Section 3.2.2 should not be difficult. However, if the user of MOBILE2 decides to calculate scrappage rates from local or more recent data, the procedure can become a formidable task. It should be noted that there are many sources of scrappage rates (i.e., U.S. DOT, R. L. Polk, Data Resources Inc.) If the user of MOBILE2 has a need for updated scrappage rates, but does not wish to calculate them, these various sources can be utilized. MOBILE2 can then be run to test the sensitivity of emission estimates to various scrappage rate estimates.

3.3 LIGHT AND HEAVY-DUTY TRUCKS

The following subsections identify the data sources, procedures, and assumptions required to estimate truck registration fractions by age for five classes of trucks. Problems associated with the estimation technique presented here are also discussed. The technique is the same for all classes of trucks, however, the value for the different variables used in estimating vehicle registration fractions by age will vary by truck classification (type).

3.3.1 Data Sources

To estimate vehicle registration fractions by age, sales data by truck classification were extracted from the MVMA Motor Vehicle Facts and Figures Annual. One of the truck weight categories in this report, 6001-10000 lbs GVW overlaps two of the truck classes listed in Section 1.2.1, LDGT2 and HDGV. It is assumed that 13 percent of the 0-10000 lb GVW trucks are 8500-10000 lbs, and the MVMA truck sales data were apportioned accordingly (U.S. DOT, 1979). Scrappage rates are listed in Table 3-7 in Section 3.3.2. The original source of Table 3-7 was the Jambekar and Johnson report. A portion of the data used to calculate scrappage rates had been extracted from the 1972 Truck Inventory and

TABLE 3-7

NATIONWIDE SCRAPPAGE RATES

Age	TRUCK CLASSIFICATIONS: All Trucks Less Than 10000 lb GVW	Gasoline Trucks Greater Than 10000 lb GVW	Diesel Trucks Greater Than 10000 lb GVW
1	.00	.00	0.0
2	.03	.05	.09
3	.07	.12	.16
4	.12	.21	.23
5	.17	.31	.29
6	.22	.31	.36
7	.27	.46	.42
8	.32	.52	.47
9	.37	.57	.52
10	.41	.62	.57
11	.45	.67	.61
12	.49	.71	.65
13	.53	.75	.69
14	.57	.80	.72
15	.60	.83	.76
16	.64	.86	.79
17	.68	.89	.81
18	.72	.92	.84
19	.75	.94	.86
20	.79	.96	.89
21	.82	.97	.91
22	.85	.98	.93
23	.88	.99	.95
24	.90	1.00	.97
25	.90		.98
26	.94		1.00
27	.95		
28	.96		
29	.98		
30	1.00		

Source: Jambekar and Johnson, 1977

Use Survey (Bureau of Census). If the MOBILE2 user decides to update the scrappage rates, the TIUS Public Use Tape will be needed. The local and state sources of light duty vehicle registrations by age mentioned in Section 3.1.1 are also potential sources of truck registrations by age data. However, some of those sources do not have trucks categorized by GVW. Nevertheless, the applicable state/local agency should be contacted for possible truck registration by age information (see Section 2.1.1 for a discussion of which agencies to contact).

3.3.2 Estimation Technique

The number of vehicles of a particular model year (age) registered in any given calendar year depends upon the number of model year vehicles originally sold (all of which are assumed to be registered) and the number of those originally sold which are scrapped. Consequently, "scrappage rates" were estimated in order to determine vehicle (truck) registrations by age by truck classification. Scrappage rates for a particular model year and type were calculated from the following formula:

$$SR_{at} = \frac{S_{MYt} - Stk_{MYt,i}}{S_{MYt}} \qquad (3\text{-}3)$$

where t = truck type (classification)

a = age of truck (i - MY)

MYt = model year, type t

i = current year

$Stk_{MY,t,i}$ = stock of MY trucks, type t, in current year i, where stock is equal to the number of model year MY, type t trucks registered in current year i

$S_{MY,t,i}$ = sales of trucks of model year MY, type t, in year i

Table 3-7 lists scrappage rates estimated from 1942 - 1972 sales and stock data. These can be updated by using equation (3-3), the most current and past MVMA Motor Vehicle Facts and Figures, and the 1977 TIUS

Public Use Tape. To estimate future scrappage rates, it is not necessary to predict future truck stocks. Since the scrappage rates are approximated using current and historical data they should be applicable to future trends. Updated scrappage rates can be calculated using current and past data by generating scrappage curves. Scrappage curves can be generated by graphically plotting scrappage rates (using equation 3-3) against vehicle age. For example, a scrappage rate for a 20 year old truck would be the scrappage rate defined by substituting S 1957,t for S MY,t and Stk 1957,t, 1977 for Stk MYt,i in equation (3-3). A few scrappage rates should be plotted for each age using historical data and a linear curve should be fit to these points (using linear regression analyses). Then, scrappage rates can be estimated from the graph and used in equation (3-4).

$$\text{Registration}_{at} = S_{MY,t} - (S_{MY,t} \times (SR_{at})) \qquad (3\text{-}4)$$

where t = age of truck

a = age (current year - MY)

MY = model year

For example, the scrappage rate applied to 1965 models in 1977 would be the difference between the original sales and the stock of 1965 trucks in 1977 divided by the original model year sales (in 1965). It follows that the number of 1965 (12 year old) vehicles registered in 1977 would be equal to:

$$\text{1965 Model Year}_t \text{ Sales} - (SR_{12,t} \times (\text{1965 Model Year}_t \text{ Sales}))$$

where $SR_{12,t}$ = scrappage rate applied to a vehicle 12 years old of type t

Tables 3-8 and 3-9 list nationwide truck sales data for 1967-1978 model years for gasoline and diesel-powered trucks. Because the MVMA truck sales data are expressed in terms of only three weight categories (0-6000,

TABLE 3-8

DOMESTIC SALES OF GASOLINE TRUCKS BY GROSS VEHICLE WEIGHT (LBS)

Model Year	6000 & Less	6001-10000	Over 10000
1978	1,211,899	1,778,725	205,109
1977	1,251,449	1,579,923	182,089
1976	1,181,906	1,266,020	178,955
1975	897,292	853,310	179,551
1974	1,409,586	660,312	255,026
1973	1,639,663	713,210	281,781
1972	1,339,226	549,523	275,994
1971	1,133,911	453,900	225,009
1970	895,238	373,327	205,303
1969	1,052,057	378,980	248,437
1968	1,069,389	364,997	247,282
1967	836,429	268,435	238,774
1966	957,168	277,594	254,381
1965	987,503	268,962	257,012
1964	839,808	213,196	241,490
1963	765,114	213,266	261,227
1962	610,600	182,198	246,729
1961	524,135	144,523	231,050
1960	534,431	146,849	265,006
1959	461,885	144,376	301,055
1958	346,209	106,553	220,456

SOURCE: MVMA Motor Vehicle Facts and Figures (various issues)

TABLE 3-9

DOMESTIC SALES OF DIESEL TRUCKS BY GROSS VEHICLE WEIGHT (LBS)

Model Year	6000 & Less	6001-10000	Over 10000
1978	34,751	840	184,324
1977	2,386	975	162,198
1976	-	1,498	105,718
1975	-	1	72,604
1974	-	-	144,702
1973	-	-	152,159
1972	-	-	129,628
1971	-	81	101,407
1970	-	268	91,533
1969	-	512	101,191
1968	33	788	82,602
1967	83	838	69,879
1966	59	436	85,054
1965	59	509	71,789
1964	55	1,087	56,037
1963	37	149	47,025
1962	55	31	38,378
1961	9	-	24,931
1960	-	-	28,186
1959	-	-	32,741
1958	-	-	22,884
1957	-	-	21,607

Source: MVMA Motor Vehicle Facts and Figures (various issues)

6000-10000, and greater than 10000 lbs GVW) an apportioning factor was used to estimate truck sales in the 6000-8500 lb and 8500-10000 lb GVW categories. It was assumed that 13 percent of the 0-10000 lb GVW sales are 8500-10000 lbs and 87 percent are 0-8500 lbs (U.S. DOT, 1979). Tables 3-10 and 3-11 show the result of this apportioning.

If truck registration fractions by age are to be estimated for years beyond 1978, Tables 3-10 and 3-11 should be updated to reflect more recent sales data. Since the data presented in these tables do not distinguish between urban and rural sales, the technique described is not specific to any one type of area. If urban or rural sales data are available, the technique above can be used to estimate registrations for both of these types of areas.

Table 3-12 shows an example calculation of nationwide vehicle registration fractions for heavy-duty gasoline trucks (greater than 8500 lb GVW). Calculations of vehicle registration fractions can be made similarly for other truck categories.

3.3.3 Problems Associated with the Estimation Technique

Again, it has been assumed that nationwide sales data and scrappage rates are representative of all localities. Furthermore, scrappage rates calculated from historical data are assumed to apply to current and future years. These assumptions produce uncertainties when used on a state/local level. Therefore, it is important to use current local data when they are available.

If the MOBILE2 user decides to spend $80 to access the TIUS Public Use Tape, scrappage rates more current than those shown in Table 3-7 can be estimated. However, knowledge of regression techniques will be needed to process the tape. Hence, the level of difficulty associated with this estimation technique varies depending on the degree to which the

TABLE 3-10

DOMESTIC SALES OF GASOLINE TRUCKS APPORTIONED INTO MOBILE2 GROSS VEHICLE WEIGHT CATEGORIES*

Model Year	6000 & Less	6001-8500	8501-10000	Over 10000
1978	1,211,899	1,389,944	388,781	205,109
1977	1,251,449	1,211,845	368,078	182,089
1976	1,181,906	947,790	318,230	178,955
1975	897,292	625,731	227,578	179,551
1974	1,409,586	391,225	269,087	255,026
1973	1,639,663	407,337	305,873	281,781
1972	1,339,226	303,986	245,537	275,994
1971	1,133,911	247,485	206,415	225,009
1970	895,238	208,414	164,913	205,303
1969	1,052,057	192,945	186,035	248,437
1968	1,069,389	178,527	186,470	247,282
1967	836,429	124,803	143,632	238,774
1966	957,168	117,075	160,519	254,381
1965	987,503	105,622	163,340	257,012
1964	839,808	76,305	136,891	241,490
1963	765,114	86,007	217,189	261,227
1962	610,600	79,134	103,064	246,729
1961	524,135	57,597	86,926	231,050
1960	534,431	58,283	88,566	265,006
1959	461,885	65,562	78,814	301,055
1958	346,209	47,694	58,859	220,456

*87% of the 0-10000 lb GVW trucks are assumed to be less than 8500 lb GVW (U.S. DOT, 1979)

TABLE 3-11

DOMESTIC SALES OF DIESEL TRUCKS APPORTIONED INTO MOBILE2 GROSS VEHICLE WEIGHT CATEGORIES*

Model Year	8500 & Less	8501-10000	Over 10000
1978**	34,751	840	184,324
1977	2,924	437	162,198
1976	1,303	195	105,718
1975	1	-	72,604
1974	-	-	144,702
1973	-	-	152,159
1972	-	-	129,628
1971	70	11	101,407
1970	233	35	91,533
1969	445	67	101,191
1968	714	107	82,602
1967	801	120	69,879
1966	431	64	85,054
1965	494	74	71,789
1964	994	148	56,037
1963	162	24	47,025
1962	75	11	38,378
1961	9	-	24,931
1959	-	-	28,186
1959	-	-	32,941
1958	-	-	22,884
1957	-	-	21,607

* 87% of the 0-10000 lb GVW trucks are assumed to be less than 8500 lb GVW (U.S. DOT, 1979)

** Because 97.6% of the 0-10,000 lb GVW trucks sold in 1978 were less than 6000 lbs (see Table 3-9) it was assumed that all of 6001-10000 lb GVW trucks sold in 1978 were greater than 8500 lb GVW.

TABLE 3-12

EXAMPLE CALCULATION OF NATIONWIDE VEHICLE REGISTRATION FRACTIONS
FOR HEAVY-DUTY GASOLINE TRUCKS (>8500 LBS GVW)

Model Year	Sales 8501-1000 lb (Table 3-10)	(1-Scrappage) Rate <10000 lb (Table 3-7)	Estimated Registrations (8501-10000 lb)	Sales >10000 lb (Table 3-10)	(1-Scrappage) Rate >10000 lb (Table 3-7)	Estimated Registrations (>10000 lb)	Total Estimated Registrations (>8500 lb)	Registration Fractions
1978	388,781	1.00	388,781	205,109	1.00	205,109	593,890	.128
1977	368,078	.97	357,036	182,089	.95	172,985	530,021	.114
1976	318,230	.93	295,954	178,955	.88	157,480	453,434	.097
1975	227,578	.88	200,269	179,551	.79	141,845	342,114	.074
1974	269,087	.83	223,342	255,026	.69	175,968	399,310	.086
1973	305,873	.78	238,581	281,781	.61	171,886	410,467	.088
1972	245,537	.73	179,242	275,994	.54	149,037	328,279	.071
1971	206,415	.68	140,362	225,009	.48	108,004	248,366	.053
1970	164,913	.63	103,895	205,303	.43	88,280	192,175	.041
1969	186,035	.59	109,761	248,437	.38	94,406	204,167	.044
1968	186,470	.55	102,559	247,282	.33	81,603	184,162	.040
1967	143,632	.51	73,252	238,774	.29	69,244	142,496	.031
1966	160,519	.47	75,444	253,886	.25	63,472	138,916	.030
1965	163,340	.43	70,236	256,744	.20	51,349	121,585	.026
1964	136,891	.40	54,756	241,490	.17	41,053	95,809	.021
1963	127,189	.36	45,788	261,227	.14	36,572	82,360	.018
1962	103,064	.32	32,980	246,729	.11	27,140	60,120	.013
1961	86,926	.28	24,339	231,050	.08	18,484	42,823	.009
1960	88,566	.25	22,142	265,016	.06	15,901	38,043	.008
1959	78,814	.21	16,551	301,055	.04	12,042	28,593	.006
1958	58,859	.18	10,595	220,456	.03	6,614	17,209	.004
							4,654,339	1.002

MOBILE2 user relies on the data presented in Section 3.3.2 as compared to generating and collecting scrappage rates and sales data.

3.4 MOTORCYCLES -- METHOD 1

The following sections discuss one method available to estimate motorcycle registration fractions by age from national data. Required data sources will be identified first, estimation procedures second, and associated problems third. This method uses the number of motorcycles registered (nationwide) by age to calculate the registration fractions for each year. It should be noted, however, that none of the methods described are considered superior to any other method available to the MOBILE2 user. Local data should be used if they are available.

3.4.1 Data Sources

The 1979 Motorcycle Statistical Annual published by the Motorcycle Industry Council, Inc. (MIC) provides comprehensive nationwide statistics on motorcycle registrations (on road and dual purpose motorcycles). Local/state estimates of motorcycle registrations by age may be available from agencies such as Councils of Government, State Departments, Associations of Government, and Regional Planning Commissions. This type of agency in the state/local area of interest should be contacted for registration by age information. If no such information exists, then the estimation techniques described in the following sections should be used.

3.4.2 Estimation Technique

Table 3-13 shows the distribution of motorcycle registrations by age calculated from nationwide data. Assuming the nationwide age distribution is relatively constant across state and local areas, motorcycle registration fractions by age can be taken directly from this table. Since Table 3-13 shows the national distribution, and does not separate

TABLE 3-13

MOTORCYCLE REGISTRATIONS -- PERCENTAGE BY AGE

Motorcycle Age (years)	Fraction of* Total Registrations
1	.133
2	.145
3	.138
4	.116
5	.123
6	.114
7	.069
8	.044
9	.024
10	.009
11+	.085
	1.000

*Based on the estimated population in use in 1978.

Source: Motorcycle Industry Council, Inc., 1979

rural and urban registrations, the data presented in Table 3-13 can be used to estimate both rural and urban registration fractions by age. However, since off-road motorcycles are not required to be registered, the motorcycle populations will differ from registrations, particularly in rural areas (where off-road motorcycle use is prevalent).

3.4.3 Problems Associated with Method 1

The key assumption made in the estimation technique discussed above is that the national age distribution of motorcycles applies to all local areas. Because motorcycle use is seasonal, the age distribution of motorcycles may vary widely according to the amount of use during each year.

3.5 MOTORCYCLES -- METHOD 2

The following sections describe an alternate method for estimating motorcycle registration fractions by age using state and national data. Section 3.5.1 describes the data source required, Section 3.5.2 the estimation technique, and Section 3.5.3 the possible problems associated with the methodology. This method uses estimated retail motorcycle sales by state and nationwide scrappage rates to estimate registration fractions by state.

3.5.1 Data Sources

The major source needed to estimate motorcycle registrations by age is the most recent Motorcycle Statistical Annual (Motorcycle Industry Council, Inc.). The data presented in the annuals are sufficient to estimate motorcycle registration fractions by age on a state level. As noted in Section 3.4.1, if local data on motorcycle registrations by age are available, they should be used instead of the estimates based on national/state data.

3.5.2 Estimation Technique

The number of motorcycles of a particular age registered in a current year depends upon the original number of on-road motorcycles sold (and assumed to be registered) and the number of those originally sold that are "scrapped". Table 3-14 lists scrappage rates for motorcycles by age. The scrappage rates are listed for motorcycles aged one to thirteen, not one to twenty, because it is assumed that the maximum life of a motorcycle is 13 years (the median operable life is about 6 years). The scrappage rate data are presented in the Motorcycle Statistical Annual (MIC, Inc.) and are updated when necessary. Therefore, the user of MOBILE2 need not estimate scrappage rates from local data, unless the user feels that national scrappage does not accurately reflect local scrappage. Alternatively, if scrappage information is available from local agencies mentioned in Section 3.4.1, it should be used instead of the scrappage rates listed in Table 3-14. Table 3-15 lists motorcycle retail sales by state for the years 1969-1978. Thus, the number of motorcycles registered in state s of age a can be calculated using the following equation:

$$TMR_{sa} = TMS_{s,MY} (1 - SR_a) \qquad (3\text{-}5)$$

where: TMR_{sa} = total motorcycle registrations of age a, in state s

$TMS_{s,MY}$ = Total motorcycle sales in state s, model year MY

SR_a = Scrappage rate for motorcycles of age a, where a = current year - MY

An example of how this equation is applied is shown in Table 3-16.

Since the data presented in Tables 3-14 and 3-15 are not broken down by type of area (rural vs. urban) the technique described can be used for estimating either rural or urban motorcycle registrations by age. However, since off-road motorcycles are not registered, the rural

TABLE 3-14

MOTORCYCLE SCRAPPAGE RATES

Age	Scrappage Rate
1	0.00
2	.02
3	.04
4	.10
5	.25
6	.45
7	.63
8	.74
9	.83
10	.90
11	.95
12	.98
13+	.99

Source: Motorcycle Industry Council, Inc., 1979.

TABLE 3-15

NEW MOTORCYCLE REGISTRATIONS BY STATE, 1969-1978

Total U.S. State	Before 1969 618,000	1969** 670,000	1970** 1,010,000	1971 928,185	1972 1,006,143	1973 1,189,789	1974 1,024,084*	1975 746,778	1976 783,100	1977 845,485	1978 764,097
Alabama	10,568	11,456	17,271	15,872	14,649	19,833	14,383	10,947	13,615	18,325	14,400
Alaska	1,330	1,442	2,174	1,998	2,198	2,474	1,431	1,985	3,025	3,631	2,636
Arizona	7,246	7,856	11,842	10,883	11,027	15,819	14,719	7,887	8,729	10,202	9,134
Arkansas	5,859	6,352	9,576	8,800	10,823	13,263	9,950	6,345	8,190	533	3,200
California	81,436	88,288	133,091	122,310	103,312	101,253	94,473	70,142	83,626	6,106	110,072
Colorado	11,509	12,478	18,810	17,286	17,298	18,888	17,199	12,093	12,104	13,792	12,572
Connecticut	5,255	5,697	8,589	7,893	9,885	12,215	9,357	7,426	8,623	9,026	8,500
Delaware	1,382	1,498	2,258	2,075	1,756	2,041	1,951	1,463	1,485	1,408	1,161
District of Columbia	1,264	1,371	2,066	1,899	1,506	1,327	860	915	661	763	519
Florida	24,290	26,334	39,698	36,482	38,619	58,860	50,213	29,772	27,770	30,890	26,994
Georgia	17,822	18,780	28,310	26,017	37,547	40,036	28,960	17,424	16,914	21,662	19,055
Hawaii	1,370	1,482	2,234	2,053	2,223	2,067	1,724	855	966	1,344	1,900
Idaho	5,845	6,337	9,553	8,779	9,076	10,559	9,646	7,477	8,898	9,937	8,623
Illinois	23,995	26,014	39,215	36,038	42,359	49,584	43,159	38,321	40,397	41,157	35,168
Indiana	17,588	19,067	28,743	26,415	29,483	36,328	31,150	21,957	21,705	24,560	21,267
Iowa	14,300	15,504	23,371	21,478	24,751	30,405	27,303	19,944	16,107	18,747	22,953
Kansas	14,666	15,900	23,969	22,027	22,772	20,183	14,165	11,116	11,575	11,594	10,231
Kentucky	4,855	5,264	7,935	7,292	10,538	15,854	14,215	11,184	9,596	10,697	8,137
Louisiana	8,123	8,806	13,275	12,200	13,469	16,296	12,058	14,109	15,809	19,749	16,487
Maine	2,113	2,290	3,454	3,174	4,109	4,646	3,717	3,475	4,941	5,243	5,244
Maryland	6,031	6,539	9,856	9,058	9,199	13,652	17,835	12,115	13,264	14,386	11,726
Massachusetts	10,326	11,195	16,876	15,509	14,421	13,791	15,671	10,772	10,400	12,231	9,815
Michigan	43,825	47,513	71,624	65,822	80,818	92,072	63,440	40,020	38,085	38,561	29,901
Minnesota	13,115	14,218	21,433	19,697	25,355	27,736	23,837	18,343	19,972	21,039	18,385
Mississippi	4,834	5,240	7,901	7,261	10,781	12,608	11,532	7,136	7,260	9,045	8,989
Missouri	16,547	17,939	27,043	24,852	28,361	31,063	25,882	18,078	17,310	16,239	13,336
Montana	6,161	6,681	10,073	9,256	9,159	9,565	7,466	6,209	5,993	7,028	5,541
Nebraska	6,225	6,748	10,174	9,350	8,564	9,833	9,673	8,155	8,637	8,413	7,037
Nevada	3,525	3,823	5,763	5,295	2,650	2,952	2,918	2,873	2,991	3,642	3,584
New Hampshire	2,947	3,195	4,816	4,426	5,233	6,947	5,624	4,007	4,842	5,668	4,152
New Jersey	12,170	13,195	19,889	18,278	26,040	23,329	22,364	15,921	19,253	20,012	17,195
New Mexico	4,189	4,541	6,846	6,291	6,377	5,578	5,021	4,767	6,591	7,881	7,529
New York	19,314	20,940	31,566	29,009	28,222	32,598	34,701	29,774	31,258	35,267	31,197
North Carolina	12,448	13,495	20,344	18,696	27,114	31,469	26,453	13,916	13,076	11,752	8,370
North Dakota	2,317	2,512	3,788	3,480	3,984	4,801	4,936	4,211	4,245	4,090	3,724
Ohio	29,149	31,602	47,639	43,780	51,548	59,913	48,938*	43,442	39,536	38,783	32,329
Oklahoma	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oregon	16,436	17,819	26,862	24,686	26,205	27,980	20,631	15,258	17,058	18,802	16,329
Pennsylvania	29,018	31,461	47,426	43,582	43,065	69,265	63,079	40,074	39,857	37,796	30,751
Rhode Island	2,074	2,249	3,390	3,115	3,807	3,794	3,589	2,252	2,542	3,166	2,440
South Carolina	3,516	3,812	5,746	5,281	8,763	15,890	14,453	8,539	6,070	5,780	4,815
South Dakota	2,160	2,342	3,530	3,244	4,509	4,861	4,991	4,041	4,532	3,481	4,216
Tennessee	12,546	13,602	20,503	18,843	23,723	28,572	20,773	13,883	12,813	12,894	11,609
Texas	35,738	38,745	58,407	53,676	52,447	75,981	61,341	49,880	57,186	68,035	61,603
Utah	8,058	8,736	13,169	12,102	12,352	11,321	9,121	8,488	9,993	10,711	9,691
Vermont	1,533	1,662	2,506	2,303	2,568	2,342	2,879	1,965	2,506	2,695	2,403
Virginia	8,897	9,645	14,540	13,362	16,809	22,169	19,953	12,040	10,974	9,770	9,840
Washington	20,127	21,820	32,894	30,229	28,920	34,670	31,509	25,189	31,483	32,544	28,708
West Virginia	13,356	14,480	21,825	20,060	16,959	14,210	10,503	7,279	7,405	7,481	5,389
Wisconsin	8,553	9,273	13,978	12,846	17,417	24,637	25,677	21,038	22,190	18,708	19,918
Wyoming	2,547	2,761	4,162	3,825	3,616	4,181	3,771	2,876	2,840	3,322	3,292

* Adjusted to include an estimate for incomplete Ohio registrations

**State totals are estimated

Source: Motorcycle Industry Council, 1978, 1979

TABLE 3-16

ESTIMATES OF MOTORCYCLE REGISTRATION FRACTIONS BY AGE FOR MICHIGAN, 1978
EXAMPLE CALCULATION

Year Sold New (Model Year)	Estimated Retail Sales (Table 3-15)	Scrappage Rate* (Table 3-14)	Estimated Registration by Model Year in 1978	Percentage of Motorcycles Registered
1978	29901	1.00	29901	.099
1977	38561	.98	37790	.125
1976	38085	.96	36562	.121
1975	40020	.90	36018	.119
1974	63440	.75	47580	.157
1973	92072	.55	50640	.167
1972	80818	.37	29903	.099
1971	65822	.26	17114	.056
1970	71624	.17	12176	.040
1969	47512	.10	4751	.016
before 1969	24184	.04	967	.003

* Percentage remaining in vehicle fleet.

motorcycle populations will not equal the number of rural motorcycle registrations.

3.5.3 Possible Problems Associated with the Above Methodology

A major assumption made in the above methodology is that nationwide scrappage rates are the same as those in local areas. This assumption could introduce bias to the motorcycle registration by age estimates. Motorcycles in urban areas may be retired faster than the "average" (nationwide) motorcycle registration estimates. Therefore, if scrappage rate estimates are available on a state/local level, they should be used instead of nationwide statistics.

In addition, the nationwide model year sales distributions may not be representative of local model year distributions, thus the national registration fractions may not accurately estimate local registration fractions. Therefore, if local model year sales data are available, they should be used in place of the national sales data.

The level of difficulty associated with the methodology described above is minimal since all the necessary data are included in Tables 3-14 and 3-15. If the MOBILE2 user decides to calculate scrappage data from local data, or decides to collect local sales and scrappage data where available, the level of diffculty will increase, more so from the increase in time and effort required to collect the data than from the actual calculations required.

REFERENCES FOR SECTION 3

Automotive News. 1979 Market Data Book Issue. Crain Automotive Group, Inc., Detroit, MI.

Jambekar, A. and Johnson, J. 1977. The Development of an Emission and Fuel Economy Computer Model for Heavy-Duty Trucks and Buses. Michigan Technological University. Houghton, MI.

McNutt, B., Dulla R., and Lax, D. February 1979. "Factors Influencing Automotive Fuel Demand," SAE Technical Paper Series No. 790226. Congress and Exposition. Detroit, MI.

Motorcycle Industry Council, Inc. 1979. Motorcycle Statistical Annual Newport Beach, CA.

Motor Vehicle Manufacturers Association. 1979. Motor Vehicle Facts and Figures. Detroit, MI.

U.S. Department of Commerce. 1972. Truck Inventory and Use Survey. Census of Transportation. Bureau of the Census. Washington, DC.

U.S. Department of Transportation. December 1979. "Light-Duty Truck Fuel Economy Standards - Model Years 1982-1985." Rulemaking Support Paper. Washington, D.C.

4. HUMIDITY

Because NO_x emissions from mobile sources are known to vary with the normal range of ambient meteorological parameters, total NO_x emissions must be adjusted to account for this variability. The key parameters are temperature, pressure, relative humidity, and saturation mixing ratio.

4.1 DATA SOURCES

The readily available source of ambient temperature and pressure and relative humidity data is the Local Climatological Data (LCD), Annual Summary with Comparative Data and the Local Climatological Data, Monthly Summary. These are historical or climatological data recorded at National Weather Service (NWS) Stations throughout the United States. One such station is located in or near practically every major urban area. Generally, copies of these summaries are available at the local NWS Station, but if not, they may be obtained from

U.S. Department of Commerce
National Climatic Center
Federal Building
Asheville, NC 28801

The annual statistics should, of course, be used when one is attempting to generate annual emissions and the monthly summary should be used when short-term emission estimates are required. Because only three hour statistics are reported on the monthly summary, that is, strictly speaking, the shortest averaging time for the emissions estimates. However, no significant accuracy would be lost if the three hour data were used to approximate one hour conditions, if desired. If more recent data are required than are available in the latest monthly summary, the local NWS Office should be able to provide that information.

Examples of both the annual and monthly summaries have been included for reference. See Figures 4-1 and 4-2.

Saturation mixing ratios can be obtained from most advanced meteorology texts or from the Smithsonian Meteorological Tables. Saturation mixing ratios for a range of temperatures and pressures have been reproduced in Table 4-1.

4.2 METHODOLOGY

MOBILE2 expresses the necessary emissions correction factor for humidity as an explicit function of a humidity (H) given as the number of grains of water vapor per pound of dry air. This poses somewhat of a problem because H is not a convenient measure of water vapor in the ambient air and is not routinely reported. The purpose of the subsequent discussion is to relate H to standard meteorological parameters and, hence, facilitate estimation of H.

The most readily available atmospheric humidity variable is the relative humidity. The relative humidity is expressed as a percentage and is defined by:

$$RH = r/r_s \times 100\%$$

where: r = the mixing ratio giving the ratio of the mass of water vapor to the mass of dry air in which the water vapor is mixed, and

rs = the saturation mixing ratio given the mixing ratio at which the air is saturated with respect to water vapor at the ambient temperature and pressure.

The desired relationship between H and RH follows immediately from the definition of the mixing ratio (r). H represents a mixing ratio that has been written in a dimensional form (grains of water vapor/pound of dry air) rather than the traditional dimensionless form of r.

Figure 4-1

Local Climatological Data

FEBRUARY 1980
WASHINGTON, D. C.
WEA SVC CONTRACT MET OBSY
WASHINGTON NATIONAL AIRPORT

MONTHLY SUMMARY

LATITUDE 38 °51 'N LONGITUDE 77 °02 'W ELEVATION (GROUND) 10 FT. STANDARD TIME USED: EASTERN WBAN #13743

DATE	TEMPERATURE °F MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65° HEATING (SEASON BEGINS WITH JULY)	COOLING (SEASON BEGINS WITH JAN.)	WEATHER TYPES ON DATES OF OCCURRENCE (1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW)	SNOW, ICE PELLETS OR ICE ON GROUND AT 07AM IN.	PRECIPITATION WATER EQUIVALENT IN	SNOW, ICE PELLETS IN.	AVG. STATION PRESSURE IN. - - - CLEV. 65 FEET M.S.L.	WIND RESULTANT DIR.	RESULTANT SPEED M.P.H.	AVERAGE SPEED M.P.H.	FASTEST MILE SPEED M.P.H.	FASTEST MILE DIRECTION	SUNSHINE MINUTES	SUNSHINE PERCENT OF POSSIBLE	SKY COVER TENTHS SUNRISE TO SUNSET	SKY COVER TENTHS MIDNIGHT TO MIDNIGHT	DATE
1	30	18*	24	-12	7	41	0			T	0	0	30.05	32	20.0	20.1	29	NW	614	100	4	2	1
2	33	19	26	-10	7	39	0			T	0	0	30.18	32	16.1	16.3	26	NW	615	100	0	0	2
3	35	20	28	-8	8	37	0			T	0	0	30.22	31	13.6	13.8	21	NW	617	100	1	2	3
4	38	25	32	-4	11	33	0			0	0	0	30.18	32	14.7	14.8	22	NW	535	86	4	4	4
5	40	23	32	-4	14	33	0			0	0	0	30.26	34	8.6	9.1	19	NW	535	86	2	3	5
6	32	28	30	-6	23	35	0	1		0	.03	.3	30.12	04	8.4	8.9	16	N	0	0	10	10	6
7	42	26	34	-2	21	31	0			0	.01	T	30.12	33	15.4	15.5	24	NW	499	80	4	5	7
8	43	28	36	0	17	29	0			0	0	0	30.32	32	10.6	10.8	17	NW	563	90	6	5	8
9	38	33	36	0	24	29	0			0	.14	2.2	30.11	31	.7	4.9	9	S	0	0	10	10	9
10	37	25	31	-5	21	34	0	1		3	.02	.4	29.89	33	9.1	9.2	22	NW	632	100	1	2	10
11	42	24	33	-3	20	32	0			1	0	0	29.94	19	2.0	3.9	12	SE	548	86	5	5	11
12	39	27	33	-4	15	32	0			0	0	0	30.04	32	10.9	11.4	24	NW	625	98	1	1	12
13	43	23	33	-4	16	32	0			0	0	0	30.31	25	4.5	6.8	12	SE	641	100	0	0	13
14	58	27	43	6	23	22	0		8	0	0	0	30.21	24	2.9	6.8	17	NW	551	86	3	3	14
15	47	36	42	5	28	23	0			0	T	0	30.03	10	3.2	6.9	12	N	35	5	10	9	15
16	47	29	38	1	30	27	0	1		0	.20	0	29.56	32	10.5	10.6	29	NW	146	23	8	7	16
17	35	22	29	-8	10	36	0			0	0	0	29.94	32	14.7	15.0	23	NW	626	98	1	1	17
18	41	19	30	-8	14	35	0			0	0	0	30.20	21	5.4	7.9	17	NW	595	91	2	1	18
19	53	27	40	2	23	25	0			0	0	0	30.14	17	5.0	6.0	12	S	485	74	10	5	19
20	62	33	48	10	32	17	0		8	0	.03	0	29.88	16	2.8	4.8	12	S	454	69	8	8	20
21	65*	42	54*	16	42	11	0			0	.01	0	29.88	34	3.5	6.3	17	NW	408	62	5	6	21
22	51	44	48	10	44	17	0	1		0	.26	0	29.82	05	5.4	6.6	11	NE	0	0	10	10	22
23	58	43	51	12	44	14	0			0	.02	0	29.82	21	1.2	5.3	11	S	162	24	9	9	23
24	62	43	53	14	40	12	0	2		0	.05	0	29.93	36	4.2	5.5	12	NW	423	63	4	5	24
25	49	38	44	5	35	21	0	1		0	.24	T	29.85	07	2.9	6.3	13	NW	13	2	10	10	25
26	38	29	34	-5	19	31	0		9	0	T	T	29.92	33	14.3	15.8	32	NW	433	64	5	8	26
27	45	28	37	-3	17	28	0			0	0	0	29.89	25	9.3	13.4	26	W	124	18	9	8	27
28	35	28	32	-8	22	33	0	1		0	.15	2.2	29.83	01	3.6	5.5	15	N	0	0	10	9	28
29	29	19	24*	-16	11	41	0			2	0	0	30.15	33	12.7	13.1	24	NW	686	98	2	2	29

SUM	SUM				TOTAL	TOTAL		TOTAL	TOTAL									TOTAL	%	SUM	SUM	
1267	826				930	0	NUMBER OF DAYS	1 16	5 1	30.03	32	5.9	9.7	32	NW	11545	FOR	153	148	
AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION	DEP.									DATE: 26	POSSIBLE	MONTH	AVG.	AVG.	
43.7	28.5	36.1	-1.2	22	29	0	.01 INCH 12	-1.29										18738	62	5.3	5.1	

NUMBER OF DAYS				SEASON TO DATE		GREATEST IN 24 HOURS AND DATES			GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
MAXIMUM TEMP.		MINIMUM TEMP.		TOTAL	TOTAL		PRECIPITATION	SNOW, ICE PELLETS	
≥ 90 °	≤ 32 °	≤ 32 °	≤ 0 °	DEP.	DEP.	THUNDERSTORMS 3			
0	3	21	0	-392	0	HEAVY FOG 1	26	22	2.6 9-10
						CLEAR 10	PARTLY CLOUDY 8	CLOUDY 11	3.1 10

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 = CALM.
DATA IN COLS. 8 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY

SUMMARY BY HOURS

HOUR LOCAL TIME	AVERAGES SKY COVER (TENTHS)	STATION PRESSURE IN.	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	RELATIVE HUMIDITY %	WIND SPEED M.P.H.	RESULTANT WIND DIRECTION	RESULTANT WIND SPEED M.P.H.
01	5	30.02	33	30	22	65	7.7	33	5.4
04	5	30.02	32	29	22	68	7.4	33	5.6
07	5	30.04	30	27	20	68	7.5	32	5.3
10	6	30.06	35	31	22	61	11.5	33	6.3
13	6	30.02	40	34	23	52	11.7	31	5.9
16	5	29.99	42	35	22	48	12.1	31	7.0
19	4	30.02	38	32	21	54	9.2	32	5.9
22	5	30.04	35	31	22	59	9.9	33	6.8

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

DATE	A. M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	P. M. HOUR ENDING AT 1	2	3	4	5	6	7	8	9	10	11	12	DATE
1																									1
2																									2
3																									3
4																									4
5																									5
6																									6
7	T	T	.01	T							T	T	.01	T	T	.01	.01	T	T	T	T	T		T	7
8																									8
9																									9
10	.01	.01	T											T	T	T	.01	.02	.03	.01	.03	.02	.01	.01	10
11																									11
12																									12
13																									13
14																									14
15																									15
16		T	T	.01	.03	.03	.02	.02	.05	02	02	T	T										T	T	16
17																									17
18																									18
19																									19
20																									20
21	.01	T																					T	.03	21
22		.05	.08	.12	T			T	T	.01	T	T	T	T	T	T									22
23																T	T	T	T	T	T	T	T	T	23
24	.03	01	.01	T												T							T	.02	24
25				.02	.12	.05	.04	.01	T	T	T	T													25
26									T	T															26
27																									27
28									T	01	03	02	.02	02	02	.02	01	T	T	T					28
29																									29

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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA AND INFORMATION SERVICE

Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

USCOMM-NOAA-ASHEVILLE 01-29-80

FEBRUARY 1980 WASHINGTON, D. C.

Figure 4-1 (Continued)

OBSERVATIONS AT 3-HOUR INTERVALS

HOUR	SKY COVER TENTHS	CEILING HNDS OF FT	VISIBILITY WHOLE MILES	VISIBILITY FRACTION MILES	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
DAY 01											
01	0	UNL	15			21	18	06	52	32	17
04	1	UNL	15			18	16	07	62	33	15
07	1	UNL	15			18	16	06	59	33	14
10	6	UNL	15			22	19	08	55	32	13
13	7	UNL	15			28	23	09	45	32	19
16	0	UNL	15			29	24	08	41	32	20
19	0	UNL	20			26	22	09	46	31	12
22	0	UNL	20			23	19	05	46	31	24
DAY 02											
01	0	UNL	15			20	17	05	52	33	16
04	0	UNL	15			19	16	06	57	32	13
07	0	UNL	15			20	17	06	54	31	13
10	0	UNL	20			26	22	09	48	32	16
13	0	UNL	20			32	26	10	39	33	19
16	0	UNL	20			32	26	08	36	31	16
19	0	UNL	20			27	22	07	42	32	13
22	0	UNL	20			24	20	06	46	32	9
DAY 03											
01	0	UNL	15			23	19	06	47	31	13
04	0	UNL	15			22	19	07	52	31	13
07	0	UNL	15			20	17	06	54	31	13
10	0	UNL	20			25	21	07	46	32	15
13	0	UNL	20			33	27	10	38	31	12
16	2	UNL	20			34	27	09	35	30	9
19	4	UNL	15			30	24	08	39	29	11
22	5	UNL	15			28	21	09	45	33	10
DAY 04											
01	10	250	15			28	22	08	46	32	10
04	10	120	15			25	21	08	48	33	12
07	10	100	15			25	20	06	44	32	12
10	7	UNL	15			30	25	11	45	32	15
13	2	UNL	15			35	28	13	40	33	13
16	0	UNL	20			37	30	14	39	32	14
19	1	UNL	15			32	27	14	47	31	13
22	0	UNL	15			30	25	14	51	33	14
DAY 05											
01	0	UNL	20			28	24	15	58	35	10
04	0	UNL	20			27	24	15	61	33	9
07	0	UNL	15			24	21	13	63	36	7
10	0	UNL	15			32	26	13	45	34	15
13	0	UNL	15			36	29	11	35	33	10
16	0	UNL	15			38	30	11	33	29	7
19	10	200	15			35	28	13	40	35	5
22	10	UNL	15			35	30	18	50	00	0
DAY 06											
01	10	UNL	12			31	28	21	66	00	0
04	10	UNL	12			31	28	21	66	00	0
07	10	100	9			30	27	19	64	05	8
10	10	70	10			31	27	19	61	07	11
13	10	9	0	12	S	30	29	26	85	05	8
16	10	10	1	8	S	31	30	27	85	06	10
19	10	12	10			30	28	25	82	02	11
22	10	UNL	10			29	28	24	82	02	14
DAY 07											
01	10	30	5		S	28	26	22	78	34	13
04	10	25	8			27	25	21	78	33	11
07	10	UNL	10			27	25	20	75	32	12
10	7	UNL	12			32	29	22	67	33	14
13	3	UNL	15			38	33	23	55	33	15
16	1	UNL	15			42	34	20	41	33	17
19	0	UNL	15			38	32	20	48	31	12
22	0	UNL	15			36	31	20	52	32	14
DAY 08											
01	0	UNL	15			33	29	19	56	33	11
04	0	UNL	20			31	27	18	59	32	9
07	2	UNL	20			29	26	18	63	32	9
10	10	UNL	20			35	30	18	50	32	13
13	8	UNL	20			40	33	18	41	31	9
16	1	UNL	15			42	33	16	35	30	11
19	8	100	15			38	31	15	39	34	6
22	5	UNL	15			37	30	15	41	32	7
DAY 09											
01	8	90	15			35	29	17	48	33	7
04	10	80	15			34	29	19	54	33	5
07	10	75	12			34	30	20	57	33	5
10	10	90	15			36	30	18	48	05	3
13	10	80	15			36	31	23	59	18	7
16	10	70	5		S	35	33	29	79	17	5
19	10	10	0	12	S	33	32	31	92	14	2
22	10	8	1	6	S	33	32	31	92	00	0
DAY 10											
01	10	8	2		S	33	32	30	89	00	0
04	5	UNL	7			30	29	27	89	33	4
07	0	UNL	12			26	24	20	78	33	8
10	1	UNL	12			29	26	19	66	32	10
13	1	UNL	15			33	29	19	56	33	15
16	0	UNL	20			36	30	19	50	32	13
19	0	UNL	20			35	29	17	48	31	6
22	0	UNL	20			32	27	16	52	34	8
DAY 11											
01	0	UNL	20			30	26	16	56	00	0
04	0	UNL	20			25	22	14	63	00	0
07	0	UNL	12			24	22	16	71	00	0
10	1	UNL	7			32	29	23	69	18	6
13	8	UNL	10			38	33	23	55	18	7
16	10	100	15			42	35	23	47	18	7
19	10	250	12			39	33	22	51	00	0
22	8	80	15			37	32	24	59	34	7
DAY 12											
01	3	UNL	15			35	32	26	70	00	0
04	2	UNL	15			36	30	18	48	29	7
07	1	UNL	15			30	25	10	43	32	17
10	2	UNL	25			33	27	11	40	33	15
13	0	UNL	25			36	29	13	39	29	12
16	0	UNL	20			38	30	12	34	33	12
19	0	UNL	20			35	28	12	38	32	9
22	0	UNL	20			30	25	14	51	34	7
DAY 13											
01	0	UNL	20			30	25	14	51	00	0
04	0	UNL	20			27	24	14	58	34	3
07	0	UNL	12			23	21	16	74	27	5
10	0	UNL	10			35	29	16	46	32	10
13	0	UNL	12			40	31	13	33	26	7
16	0	UNL	15			42	33	15	33	23	10
19	0	UNL	15			36	30	17	46	20	6
22	0	UNL	15			32	28	20	61	19	6
DAY 14											
01	0	UNL	15			30	27	22	72	00	0
04	0	UNL	15			29	26	20	69	21	2
07	0	UNL	7			28	26	20	72	19	2
10	0	UNL	5		KH	36	32	26	67	18	6
13	3	UNL	10			51	40	24	35	17	7
16	8	UNL	12			57	43	21	24	23	12
19	9	UNL	15			52	41	23	31	33	8
22	2	UNL	15			45	38	29	54	33	10
DAY 15											
01	1	UNL	15			38	34	27	65	35	6
04	10	50	15			40	38	30	68	02	10
07	10	50	15			39	35	29	67	00	0
10	10	60	9			40	35	26	57	08	6
13	10	100	8			43	36	25	49	17	5
16	10	60	10			44	37	28	53	14	7
19	10	50	10			40	35	28	62	12	6
22	10	55	10			40	36	29	65	16	8
DAY 16											
01	10	50	7			39	36	32	76	00	0
04	10	47	6		R	38	36	34	86	00	0
07	10	50	4		RF	40	39	38	93	00	0
10	10	40	2	8	RF	43	42	40	89	31	7
13	10	70	8		F	44	41	38	80	31	15
16	3	UNL	15			41	34	23	49	33	19
19	0	UNL	15			35	30	18	50	33	13
22	1	UNL	15			32	27	16	52	33	20
DAY 17											
01	3	UNL	20			28	24	12	51	32	14
04	0	UNL	20			26	22	11	53	32	11
07	1	UNL	20			24	20	10	55	32	13
10	2	UNL	20			28	23	09	45	33	10
13	2	UNL	20			33	27	10	38	32	14
16	2	UNL	20			34	27	08	33	30	14
19	0	UNL	20			30	24	07	37	31	11
22	0	UNL	20			25	21	09	50	33	9
DAY 18											
01	0	UNL	20			24	20	09	53	32	10
04	0	UNL	20			24	20	09	53	00	0
07	0	UNL	20			19	17	10	68	23	5
10	1	UNL	15			31	26	12	45	23	10
13	1	UNL	15			37	30	14	39	18	11
16	5	UNL	15			41	32	14	33	20	5
19	0	UNL	15			36	31	22	57	19	6
22	0	UNL	15			35	30	19	52	18	8
DAY 19											
01	0	UNL	15			33	30	24	70	17	7
04	0	UNL	15			30	28	23	75	00	0
07	2	UNL	10			27	25	19	72	21	4
10	10	UNL	12			37	32	22	55	18	8
13	10	UNL	15			43	39	22	35	17	7
16	10	250	15			50	40	24	36	18	9
19	3	UNL	15			45	36	22	40	15	2
22	4	UNL	15			38	34	26	62	07	5
DAY 20											
01	6	50	15			35	31	25	67	06	5
04	1	UNL	15			35	31	25	67	05	2
07	9	50	6		H	35	31	25	67	00	0
10	10	250	4		H	43	37	27	53	06	2
13	8	UNL	8			56	46	34	44	14	2
16	5	UNL	12			58	49	40	51	18	8
19	8	250	12			51	45	39	64	18	6
22	10	90	15			48	45	41	77	20	8
DAY 21											
01	10	40	7		H	46	45	44	93	18	3
04	8	70	12			44	44	43	96	20	3
07	8	35	8			43	42	41	93	24	2
10	5	UNL	10			52	48	45	77	03	7
13	4	UNL	12			62	53	44	52	32	12
16	7	250	15			60	50	40	48	33	9
19	3	UNL	15			50	44	38	64	02	6
22	10	250	15			49	44	39	69	06	2
DAY 22											
01	10	40	15			51	46	40	66	11	7
04	10	27	3		RF	45	44	42	89	07	9
07	10	7	3		F	45	43	41	86	05	6
10	10	3	0	12	LF	45	44	43	93	04	6
13	10	3	1		F	47	46	45	93	05	6
16	10	5	1	12	F	50	49	48	93	00	6
19	10	4	1	12	LF	49	48	48	96	04	6
22	10	3	0	10	LF	49	48	48	96	34	6
DAY 23											
01	10	4	2		F	47	46	45	93	32	5
04	10	250	3		F	43	43	42	96	33	6
07	10	200	1		F	43	43	42	96	18	6
10	10	UNL	0	8	F	46	46	45	96	18	7
13	10	80	10			55	51	47	75	18	8
16	10	38	10		RW	57	51	45	64	00	0
19	10	80	7			50	47	44	80	03	5
22	10	50	7			50	47	44	80	00	0
DAY 24											
01	10	15	4		RF	49	48	47	93	20	3
04	6	24	7			47	47	46	96	00	0
07	2	UNL	7			45	43	41	86	01	3
10	2	UNL	10			53	47	41	64	04	5
13	4	UNL	12			58	49	39	49	06	3
16	5	UNL	15			59	50	40	50	35	9
19	3	UNL	15			52	45	36	55	35	7
22	8	50	15			50	42	32	50	36	8
DAY 25											
01	10	100	15			48	41	32	54	01	7
04	10	18	4		RW	44	41	38	80	33	8
07	10	5	3		RF	39	38	36	89	06	5
10	10	11	5		F	40	39	37	89	08	5
13	10	45	6		H	43	40	36	78	07	6
16	10	30	6		H	44	40	34	68	14	4
19	8	50	7			41	38	33	73	15	5
22	10	18	7			40	37	33	76	16	4
DAY 26											
01	10	50	7			38	36	33	82	07	5
04	10	70	8			38	36	33	82	35	9
07	10	UNL	9			36	32	25	64	35	17
10	10	33	12			36	32	25	64	35	15
13	6	UNL	20			37	30	17	44	32	22
16	0	UNL	20			35	27	08	52	31	24
19	0	UNL	25			32	25	04	50	32	12
22	10	UNL	20			30	24	06	56	32	6
DAY 27											
01	10	120	20			30	24	08	39	22	5
04	10	90	20			30	25	13	49	21	12
07	10	80	15			31	26	15	51	19	7
10	10	80	15			35	29	17	48	21	14
13	8	100	15			43	34	18	37	21	11
16	9	45	15			44	36	21	40	29	14
19	6	35	15			42	34	20	41	29	14
22	9	35	15			39	33	22	51	32	16
DAY 28											
01	7	UNL	15			33	28	17	52	33	13
04	10	UNL	20			30	26	16	56	35	3
07	10	90	30			32	27	14	47	00	0
10	10	6	0	8	S	30	29	24	78	11	2
13	10	8	0	12	SF	30	28	25	82	09	2
16	10	8	2		SF	30	29	26	85	07	8
19	10	10	10		S	31	29	25	79	03	3
22	10	30	8			30	28	25	82	33	7
DAY 29											
01	0	UNL	15			28	27	23	92	30	8
04	0	UNL	15			24	22	17	74	25	11
07	0	UNL	15			20	18	11	68	33	5
10	3	UNL	20			26	22	10	51	34	11
13	3	UNL	20			26	22	10	51	31	12
16	3	UNL	20			28	23	08	43	33	15
19	0	UNL	20			23	19	04	44	32	16
22	0	UNL	20			20	17	02	45	32	13

STATION

WASHINGTON D C NATL AP

YEAR & MONTH

80 02

NOTES

CEILING

UNL INDICATES UNLIMITED

WEATHER

+	TORNADO
T	THUNDERSTORM
Q	SQUALL
R	RAIN
RW	RAIN SHOWERS
ZR	FREEZING RAIN
L	DRIZZLE
ZL	FREEZING DRIZZLE
S	SNOW
SP	SNOW PELLETS
IC	ICE CRYSTALS
SW	SNOW SHOWERS
SG	SNOW GRAINS
IP	ICE PELLETS
A	HAIL
F	FOG
IF	ICE FOG
GF	GROUND FOG
BD	BLOWING DUST
BN	BLOWING SAND
BS	BLOWING SNOW
BY	BLOWING SPRAY
K	SMOKE
H	HAZE
D	DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS; MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-210

U.S.MAIL
FIRST CLASS

Figure 4-2

Local Climatological Data

Annual Summary With Comparative Data

1978

WASHINGTON, D.C.

NATIONAL AIRPORT

Narrative Climatological Summary

Washington lies at the western edge of the middle Atlantic coastal plain, about 50 miles east of the Blue Ridge Mountains and 35 miles west of Chesapeake Bay at the junction of the Potomac and Anacostia Rivers. Elevations range from a few feet above sea level to about 400 feet in parts of the northwest section of the city.

Observational records have been kept continuously since November 1870. Since June 1941, the official observations have been taken at Washington National Airport. Significant temperature differences within the metropolitan area are not unusual. Average minimum temperatures at some locations are 8° lower than official airport readings. Minimum temperatures for the airport are highest for the area since the airport is located near the center of the urban heat island. Variations in the average maximum temperatures over the metropolitan area are usually less than 5°. Rainfall and snowfall amounts at the airport are less than an average for the area; some locations average 5 inches more precipitation than the airport per annum.

Summers are warm and humid and winters mild; generally pleasant weather prevails in the spring and autumn. The coldest weather occurs in late January and early February. The warmest weather occurs late in July. There are no well pronounced wet and dry seasons. Thunderstorms, during the summer months, often bring sudden and heavy rain showers and may be attended by damaging winds, hail, or lightning. On June 9, 1929, a violent local thunderstorm was accompanied by wind gusts up to 100 m.p.h. Two severe hailstorms with resultant damage of $100,000 or more are recorded, one in April 1938 and the other in May 1953. Tornadoes rarely occur, but three rather destructive ones have been recorded - one in April 1923 and one in November 1927; the resulting damage was $100,000 or more in each case. In April 1973 a tornado struck in the vicinity of suburban Fairfax, Virginia causing an estimated $15,000,000 damage.

Tropical disturbances occasionally, during their northward passage, influence Washington's weather mainly with high winds and heavy rainfall, but extensive damage from wind and tidal flooding is rare.

With the passage of Hurricane Hazel on October 15, 1954, the peak gust of wind reached 98 m.p.h., but only 1.73 inches of rainfall was recorded. Hurricane Connie, August 12-13, 1955, produced 6.60 inches of rainfall but the peak wind was only 58 m.p.h. During June 21-22, 1972, Hurricane Agnes produced 7.52 inches of rain at Washington National Airport. Flooding from the rains of Agnes caused 16 deaths in the greater metropolitan area and damage totaled $300,000,000 in Virginia, Maryland, Delaware and the District of Columbia.

In recent years, urban flooding caused by locally heavy rains has become a major problem. The most critical flooding is associated with the Alexandria portion of Four Mile Run in nearby Virginia but other streams in the Metropolitan Area are flooding with increasing frequency.

Occasional overflows from the Potomac River result from heavy rain over the basin, at times augmented by melting snow. In a few cases during cold winters ice forms on the river and in spring flooding is caused by ice gorges when the ice breaks up. The river is in tidewater and above normal tides associated with hurricane or severe storms along the coast cause flooding at times. Major floods occurred in June 1972, October 1954 and 1942, April 1937, March 1936 and August 1933. In 1954 and 1933 the flooding resulted mainly from high tides caused by hurricane winds. In 1942 the flooding was a combination of heavy rain and tidal flooding. In the other cases the flooding resulted mainly from heavy rain in the Potomac basin.

Snow accumulations of more than 10 inches are relatively rare. Usually the melt-off is rapid, but snow depths of 3 or more inches make driving hazardous, and slows or halts traffic. Schools may be closed and community activities may be temporarily disorganized, but usually conditions improve within a day or two. The first significant snow accumulation of a season is often the most disruptive.

The greatest recorded snowfall from a single storm was 28 inches. This is known as the Knickerbocker Storm and occurred in two days of January 1922. The snowfall accumulation collapsed the roof of the Knickerbocker Theater and resulted in the loss of many lives. Snowfalls of this magnitude are rare.

Records of the past 20 years show the average date of the last freezing temperature in the spring to be March 29 and the latest April 16. The average date of the first freezing temperature in the fall is November 10 and the earliest October 20.

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA AND INFORMATION SERVICE / NATIONAL CLIMATIC CENTER ASHEVILLE, N.C.

Figure 4-2
(Continued)

Average Temperature

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1939	37.8	42.9	46.4	53.4	68.0	73.4	78.2	76.8	71.0	58.4	48.0	40.1	57.8
1940	36.9	37.1	46.7	56.8	64.4	76.8	77.5	73.4	66.8	55.9	48.2	42.8	56.8
#1941	34.8	33.9	39.8	60.6	66.8	73.2	77.0	73.4	72.4	58.1	41.4	37.9	
1942	36.0	36.1	46.8	58.2	68.4	74.0	78.0	74.8	70.3	59.8	47.8	36.4	56.8
1943	35.8	38.7	44.4	51.1	66.8	76.8	78.0	78.0	67.6	58.4	46.8	38.0	56.6
1944	37.2	37.8	42.4	53.4	70.8	76.8	78.2	75.8	70.8	56.8	47.4	34.2	56.6
#1945	30.8	38.4	35.9	59.4	63.0	76.4	78.4	74.8	72.8	57.8	49.3	32.9	57.1
#1946	38.8	39.2	39.9	58.0	65.2	72.4	78.2	72.4	76.0	61.4	51.8	41.4	58.0
#1947	41.7	31.4	40.0	57.8	64.4	71.8	73.5	79.0	69.8	64.9	48.2	38.0	58.9
#1948	28.8	36.8	48.0	59.4	64.4	74.0	78.0	73.8	69.4	56.2	51.4	40.2	58.6
1949	42.6	42.8	48.6	55.0	66.0	73.1	81.0	77.4	67.1	63.4	48.1	41.9	59.0
1950	48.0	38.7	41.7	52.4	64.5	73.8	78.2	73.6	66.9	61.0	47.9	35.6	56.9
1951	39.5	38.6	45.4	55.8	64.9	73.4	78.7	76.8	70.3	62.1	44.1	40.9	57.6
1952	40.7	41.1	43.3	57.3	64.2	76.8	80.5	79.2	68.4	55.8	48.2	38.4	57.6
1953	40.7	42.6	47.9	56.1	70.1	76.4	79.6	76.9	69.7	60.8	48.1	40.4	58.9
1954	35.9	43.9	46.9	59.4	62.8	76.4	78.8	75.2	73.3	62.0	45.2	37.1	57.7
1955	35.4	37.8	47.1	58.2	67.1	76.2	82.1	78.3	69.9	59.4	45.5	33.4	57.1
1956	34.5	41.1	45.2	53.4	63.4	73.3	77.6	75.0	66.4	59.0	46.1	44.2	56.3
1957	32.9	41.6	45.8	59.2	67.2	76.4	79.2	75.7	71.9	55.4	49.0	41.4	58.0
1958	34.4	31.2	41.4	57.1	65.2	71.8	79.1	75.4	69.1	59.1	49.9	32.9	55.3
1959	34.9	39.0	43.4	58.3	69.8	76.0	78.5	80.5	73.2	62.5	48.4	42.0	58.9
#1960	38.2	39.8	39.6	61.2	65.7	74.1	77.0	78.5	71.9	58.7	48.5	31.0	58.3
1961	29.8	38.3	47.8	52.0	62.2	73.2	78.4	77.4	74.8	59.5	50.3	38.4	56.7
1962	34.4	39.6	44.2	56.2	68.7	73.8	79.3	76.8	67.0	60.5	44.8	33.2	55.8
1963	31.4	31.0	48.8	57.4	64.4	73.8	77.4	75.4	66.3	61.2	49.8	31.5	55.7
1964	36.3	38.9	47.8	56.1	68.1	76.0	79.2	75.8	69.8	59.1	51.0	39.8	57.5
1965	33.4	36.8	41.4	51.8	69.1	72.4	78.8	77.2	72.4	57.9	49.3	41.3	56.8
1966	32.4	38.2	47.4	52.7	65.0	76.0	80.9	78.7	68.4	57.0	49.5	37.8	56.8
1967	41.0	34.0	43.3	57.4	60.0	74.7	77.2	78.2	68.0	57.8	45.0	39.9	56.4
1968	31.4	34.8	44.7	58.0	63.7	74.1	79.4	77.2	72.0	61.1	50.0	36.4	57.5
1969	34.2	38.4	43.0	58.7	68.4	77.1	79.3	78.8	70.1	58.8	47.2	38.3	57.2
1970	30.0	37.1	41.8	55.3	68.1	75.2	79.2	79.0	73.0	62.5	49.3	39.7	57.7
1971	31.3	39.1	49.2	53.0	63.7	75.4	78.3	76.7	73.0	66.7	48.2	43.5	57.9
1972	38.5	36.5	49.4	56.1	66.4	78.2	77.8	75.4	71.0	58.0	48.8	43.4	58.7
1973	37.4	37.0	51.1	56.0	62.6	77.1	79.2	78.4	74.1	63.9	51.4	41.1	59.3
1974	42.4	39.2	49.2	58.3	65.1	71.5	79.0	78.4	70.2	57.3	50.4	43.1	58.8
1975	40.4	40.4	49.2	55.6	69.1	76.4	79.4	80.1	68.5	63.2	54.4	40.5	59.4
1976	33.4	44.4	51.3	59.4	65.0	77.4	78.4	78.7	70.4	55.4	43.1	35.5	57.9
1977	25.4	38.4	52.7	60.1	69.4	76.1	80.2	78.8	73.4	59.1	51.8	38.1	58.6
1978	32.5	31.4	44.4	57.7	65.8	76.1	78.5	81.3	73.4	59.4	52.2	43.1	58.1
RECORD MEAN	33.1	37.8	46.0	56.3	65.4	74.5	78.5	77.1	70.5	59.5	48.5	38.4	57.4
MAX	43.3	48.5	55.1	66.8	73.7	83.0	87.5	85.8	79.4	69.0	57.2	45.9	66.3
MIN	28.0	29.3	36.8	45.8	57.4	65.1	69.5	68.3	61.5	49.8	39.8	30.9	48.4

Heating Degree Days

WASHINGTON, DC
WASHINGTON NATIONAL AIRPORT

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
1938-39	0	0	24	203	647	987	926	721	601	222	39	6	4176
1939-40	0	0	28	194	545	704	824	765	905	200	103	0	4270
#1940-41	0	0	7	219	489	1048	1051	740	536	399	123	6	4661
1941-42	0	0	10	181	459	862	932	848	642	302	60	0	4322
1942-43	0	0	59	182	399	981	1034	926	505	265	87	1	4639
1943-44	0	0	70	129	449	1062	892	810	536	329	54	4	4315
1944-45	0	0	29	300	415	771	974	785	724	395	27	24	4444
1945-46	0	1	18	234	498	723	1001	800	535	374	99	11	4294
1946-47	0	0	41	244	462	963	735	859	611	249	178	9	4227
1947-48	0	0	34	260	592	773	1033	989	471	216	67	0	4332
1948-49	0	0	0	183	445	875	949	782	671	206	40	0	4130
1949-50	0	0	18	224	525	883	1077	773	713	299	98	0	4599
1950-51	0	0	20	197	328	732	956	924	415	226	80	0	3413
1951-52	0	0	11	304	652	907	1221	729	389	168	72	3	4639
1952-53	0	0	4	194	606	929	1031	933	633	219	96	0	4304
1953-54	0	0	9	197	378	671							

Cooling Degree Days

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1969	0	0	0	24	151	367	458	360	180	39	1	0	1580
1970	0	0	0	10	146	311	449	442	324	60	0	0	1742
1971	0	0	0	0	92	337	422	372	258	60	22	0	1523
1972	0	0	0	8	50	184	393	346	195	8	2	0	1186
1973	0	0	0	21	67	371	448	469	288	57	3	0	1704
1974	0	0	0	33	96	325	441	422	192	17	27	0	1437
1975	1	0	0	12	177	344	448	475	132	50	15	0	1654
1976	0	0	1	92	86	383	424	370	179	15	0	0	1554
1977	0	0	0	49	177	289	496	434	274	18	13	0	1762
1978	0	0	10	10	117	338	434	314	274	23	0	0	1732

Precipitation

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
1939	3.41	3.71	2.89	3.78	0.41	4.33	2.01	3.22	6.90	4.06	1.40	2.20	40.54
1940	2.12	2.77	3.42	0.19	3.10	0.86	5.79	5.00	1.34	2.15	5.26	2.27	40.21
#1941	3.04	0.98	2.57	2.73	1.58	4.38	3.57	2.30	0.93	0.99	0.58	3.28	26.87
1942	2.19	1.59	3.87	0.26	3.51	3.73	4.31	11.61	2.64	8.18	1.92	4.25	48.02
1943	2.37	2.02	3.86	2.88	5.80	2.30	1.79	0.37	1.88	3.15	4.21	1.45	31.96
1944	2.36	2.31	0.85	2.99	1.11	2.77	3.82	8.01	4.97	2.39	3.14	2.97	41.48
1945	2.09	2.80	0.66	3.18	3.06	3.31	11.06	2.82	3.93	1.34	4.24	4.71	43.33
1946	1.82	2.32	1.87	1.95	6.99	1.40	3.14	5.79	2.72	2.77	1.33	1.72	33.82
1947	3.81	1.47	1.02	2.48	4.44	6.80	3.47	1.81	4.70	1.23	4.20	1.36	36.65
1948	4.57	1.97	3.66	3.05	8.87	3.44	4.31	9.00	3.19	3.09	6.00	4.09	57.54
1949	5.28	2.68	3.42	1.94	6.33	2.42	4.22	4.09	3.49	3.27	0.94	1.98	39.86
1950	1.91	2.72	4.17	1.86	9.76	3.14	3.11	7.32	8.73	3.39	2.87	2.72	47.90
1951	2.18	2.09	2.92	3.49	2.74	6.69	5.23	1.75	2.67	1.87	4.79	4.34	41.34
1952	4.68	1.77	3.76	3.97	4.73	3.08	4.46	3.20	4.06	0.84	0.33	2.99	47.43
1953	4.13	2.35	7.43	4.77	10.69	2.98	2.72	3.48	4.07	3.75	1.50	3.32	51.17
1954	2.30	0.69	3.47	3.30	2.98	1.24	1.70	3.13	0.83	4.06	1.78	2.82	28.28
1955	0.31	3.13	3.70	2.57	3.38	2.76	2.32	14.31	0.89	0.46	1.63	0.22	41.44
1956	1.99	2.82	3.35	2.84	2.17	2.68	5.58	1.96	3.70	2.82	2.81	3.02	35.20
1957	2.81	2.75	2.23	2.79	3.40	3.02	1.05	2.44	3.57	2.49	2.87	3.02	32.78
1958	2.51	4.14	5.65	4.92	2.77	3.21	7.15	6.49	2.57	2.35	2.04	1.92	45.62
1959	2.21	1.31	2.40	4.01	2.89	5.35	4.38	2.87	2.05	2.43	2.22	3.26	39.38
1960	2.66	3.89	2.08	3.15	4.35	2.53	4.61	4.13	4.17	2.34	0.99	2.45	38.99
1961	3.12	3.71	4.18	3.24	2.57	4.84	3.99	6.31	1.02	2.37	1.79	2.88	41.96
1962	1.59	3.65	2.83	2.99	3.48	2.49	1.83	0.55	2.04	1.93	5.12	3.33	33.07
1963	1.86	1.94	2.53	0.99	1.06	6.87	1.95	7.21	3.01	T	6.70	1.72	39.34
1964	3.98	3.88	2.53	4.37	1.46	1.30	1.87	1.89	3.07	1.36	1.42	2.87	29.48
1965	2.73	1.89	4.39	1.68	1.72	1.88	2.98	4.44	2.12	2.32	0.37	0.49	26.94
1966	3.95	3.37	1.44	3.39	2.76	2.02	0.93	1.87	6.87	4.72	1.50	3.28	38.02
1967	1.35	2.27	3.49	0.80	4.27	1.51	5.24	9.17	0.20	1.77	2.10	5.93	39.15
1968	1.97	0.49	3.66	1.93	4.23	7.40	1.31	3.95	2.97	3.17	3.82	2.42	36.83
1969	1.49	2.04	1.60	1.71	1.20	3.48	9.44	6.98	3.07	1.14	2.39	6.34	43.30
1970	1.24	2.99	2.89	5.39	2.79	2.80	8.12	1.09	1.97	2.05	3.77	3.33	39.62
1971	1.86	5.44	1.93	2.19	0.80	1.72	4.97	7.18	2.68	6.12	3.76	1.86	48.02
1972	2.69	5.29	2.27	3.99	4.78	11.93	3.43	2.82	1.27	3.36	6.05	4.25	51.97
1973	2.26	2.68	2.99	4.19	3.39	2.11	2.68	4.61	1.38	1.71	0.97	4.01	34.98
1974	2.66	0.99	4.21	2.26	4.37	3.40	1.19	5.77	4.39	1.13	1.24	4.43	35.96
1975	3.09	1.36	3.33	2.13	4.71	2.19	7.16	3.34	12.36	2.38	2.05	4.04	50.33
1976	3.36	1.39	2.91	1.17	3.57	1.21	4.54	2.13	7.23	7.76	0.65	1.79	38.07
1977	1.30	0.64	2.17	2.64	1.73	3.28	4.06	4.74	0.32	5.25	4.61	4.86	39.14
1978	7.11	0.42	4.48	1.28	3.13	2.48	4.28	3.89	1.01	1.16	2.31	4.00	39.36
RECORD MEAN	2.71	2.44	3.34	2.79	3.88	3.44	4.11	4.71	3.30	2.92	2.93	3.23	39.82

Snowfall

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
1939-40	0.0	0.0	0.0	0.0	0.0	0.4	14.3	4.3	0.4	0.3	0.0	0.0	25.3
1940-41	0.0	0.0	0.0	1.9	T	T	T	3.2	2.0	11.2	0.0	0.0	18.3
1941-42	0.0	0.0	0.0	0.0	0.0	0.2	1.9	0.1	11.5	0.0	0.0	0.0	13.6
1942-43	0.0	0.0	0.0	0.0	0.0	9.7	8.2	0.7	7.9	T	0.0	0.0	26.5
#1943-44	0.0	0.0	0.0	0.0	T	0.1	2.0	2.5	T	T	0.0	0.0	4.6
1944-45	0.0	0.0	0.0	0.0	T	1.5	2.8	3.0	T	0.0	0.0	0.0	7.3
1945-46	0.0	0.0	0.0	0.0	T	10.3	6.8	4.9	T	0.0	0.0	0.0	21.6
1946-47	0.0	0.0	0.0	0.0	0.0	2.2	4.1	10.3	3.4	0.0	0.0	0.0	20.0
1947-48	0.0	0.0	0.0	0.0	T	3.8	12.1	T	T	0.0	0.0	0.0	21.4
1948-49	0.0	0.0	0.0	0.0	T	T	0.3	T	3.1	T	0.0	0.0	3.4
1949-50	0.0	0.0	0.0	0.0	T	T	T	0.3	T	T	0.0	0.0	0.3
1950-51	0.0	0.0	0.0	0.0	1.0	3.8	0.8	3.0	1.0	3.0	0.0	0.0	12.6
1951-52	0.0	0.0	0.0	0.0	T	4.8	1.8	T	3.8	0.0	0.0	0.0	10.2
1952-53	0.0	0.0	0.0	0.0	1.7	2.0	1.3	0.2	3.1	T	0.0	0.0	8.3
1953-54	0.0	0.0	0.0	0.0	6.7	T	11.3	T	T	T	0.0	0.0	18.0
1954-55	0.0	0.0	0.0	T	0.0	0.1	2.8	4.2	T	0.0	0.0	0.0	7.1
1955-56	0.0	0.0	0.0	0.0	2.3	0.9	4.3	T	4.0	0.0	0.0	0.0	11.5
1956-57	0.0	0.0	0.0	0.0	T	0.2	10.1	1.8	2.2	0.1	0.0	0.0	14.2
1957-58	0.0	0.0	0.0	T	0.3	12.0	0.3	17.2	10.6	0.0	0.0	0.0	40.4
1958-59	0.0	0.0	0.0	0.0	T	T	0.9	4.0	T	T	0.0	0.0	4.9
1959-60	0.0	0.0	0.0	0.0	T	T	T	T	7.2	17.1	0.0	0.0	24.3
1960-61	0.0	0.0	0.0	0.0	T	8.7	13.6	18.3	T	T	0.0	0.0	40.3
1961-62	0.0	0.0	0.0	0.0	1.3	1.2	2.0	6.5	4.0	0.0	0.0	0.0	15.0
1962-63	0.0	0.0	0.0	0.0	T	14.2	2.1	2.3	1.1	0.0	T	0.0	21.6
1963-64	0.0	0.0	0.0	0.0	T	0.6	8.9	11.7	0.2	0.4	0.0	0.0	33.8
1964-65	0.0	0.0	0.0	0.0	0.2	0.3	9.1	1.9	5.4	0.0	0.0	0.0	17.1
1965-66	0.0	0.0	0.0	0.0	0.0	0.0	7.2	21.3	0.9	T	0.0	0.0	29.4
1966-67	0.0	0.0	0.0	0.0	T	16.1	1.3	19.0	0.7	0.0	0.0	0.0	37.1
1967-68	0.0	0.0	0.0	0.0	0.9	0.3	2.8	2.4	3.0	0.0	0.0	0.0	9.4
1968-69	0.0	0.0	0.0	0.0	T	T	0.2	2.6	0.7	0.0	0.0	0.0	3.5
1969-70	0.0	0.0	0.0	0.0	T	0.8	3.6	T	T	0.0	0.0	0.0	4.4
1970-71	0.0	0.0	0.0	0.0	T	9.2	4.8	0.3	1.6	T	0.0	0.0	15.9
1971-72	0.0	0.0	0.0	0.0	1.4	0.1	0.3	14.4	T	5.6	0.0	0.0	14.8
1972-73	0.0	0.0	0.0	T	T	0.0	T	0.1	T	T	0.0	0.0	0.1
1973-74	0.0	0.0	0.0	0.0	0.0	11.0	1.3	4.2	T	T	0.0	0.0	16.7
1974-75	0.0	0.0	0.0	T	T	0.1	0.8	9.8	0.3	T	0.0	0.0	10.9
1975-76	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.9	0.8	0.0	0.0	0.0	2.2
1976-77	0.0	0.0	0.0	0.0	0.0	0.6	9.7	0.0	T	0.0	0.0	0.0	11.1
1977-78	0.0	0.0	0.0	0.0	0.1	0.2	10.3	3.0	8.3	0.9	0.0	0.0	22.9
1978-79	0.0	0.0	0.0	0.0	3.1	T							
RECORD MEAN	0.0	0.0	0.0	T	0.5	3.6	4.9	4.8	2.5	T	T	0.0	18.9

# Indicates a station move or relocation of instruments. See Station Location table.

Record mean values above are means through the current year for the period beginning in 1872 for temperature, 1871 for precipitation, and 1944 for snowfall. Temperature, precipitation, and heating degree day data are from City Office sites through June 1941 and from Airport sites thereafter. Snowfall data are from City Office sites through 1943 and from Airport sites thereafter.

Meteorological Data For The Current Year

Station: WASHINGTON, D. C. #13743 — WASHINGTON NATIONAL AIRPORT — Standard time used: EASTERN — Latitude: 38° 51' N — Longitude: 77° 02' W — Elevation (ground): 10 feet — Year: 1978

Month	Temperature °F: Averages: Daily maximum	Daily minimum	Monthly	Extremes: Highest	Date	Lowest	Date	Degree days Base 65 °F: Heating	Cooling	Precipitation in inches: Water equivalent: Total	Greatest in 24 hrs.	Date	Snow, ice pellets: Total	Greatest in 24 hrs.	Date	Relative humidity, pct: Hour 01 (Local time)	Hour 07 (Local time)	Hour 13 (Local time)	Hour 19 (Local time)	Wind: Resultant: Direction	Speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Date	Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperature °F: Maximum (b) 90° and above	32° and below	Minimum 32° and below	0° and below	Average station pressure mb. Elev. 65 feet m.s.l.
JAN	39.4	25.9	32.5	62	9	10	10	1001	0	7.11	2.03	25-26	10.3	4.6	13	63	65	53	56	30	9.7	11.0	35	SW	26	41	6.9	6	7	18	12	3	0	2	0	3	27	0	1015.6
FEB	38.3	24.9	31.4	54	25	18	7	933	0	0.42	0.20	5-6	3.8	2.2	5-6	58	61	45	51	33	0.6	10.0	36	NW	6	80	5.0	12	5	11	5	2	0	0	3	26	0	1016.9
MAR	52.3	36.4	44.4	79	21	16	5	633	0	4.48	2.41	25-26	8.3	4.1	3	59	65	49	51	33	4.6	11.2	45	NW	19	44	6.8	7	5	19	10	2	2	0	0	0	10	0	1015.9
APR	68.1	47.3	57.7	88	1	40	16	219	10	1.38	0.82	18-19	0.0	0.0		54	57	38	39	32	3.3	11.7	40	SW	1	65	6.4	7	11	12	8	0	1	0	0	0	0	0	1012.5
MAY	74.9	57.1	66.0	88	26	42	2	86	117	5.13	1.51	14-15	0.0	0.0		74	73	57	62	04	1.0	9.4	27	E	4	52	6.8	8	7	16	12	0	0	2	0	0	0	0	1012.5
JUN	86.4	67.0	76.7	97	27	54	14	0	358	2.43	0.73	26-27	0.0	0.0		73	70	49	58	24	2.8	10.3	49	NW	27	78	4.8	13	11	6	11	0	7	0	0	0	0	0	1015.2
JUL	87.0	70.6	78.8	100	23	62	13	0	434	4.28	1.79	2-3	0.0	0.0		80	81	59	65	20	1.5	9.0	26	W	8	72	5.4	12	10	9	10	0	3	0	13	0	0	0	1014.2
AUG	88.7	71.8	81.3	93	29	65	22	0	514	5.85	2.03	30-31	0.0	0.0		85	86	62	70	20	2.6	8.1	47	SE	5	70	6.6	6	10	15	13	0	7	0	15	0	0	0	1015.9
SEP	82.0	69.1	75.6	94	19	50	29	9	274	1.01	0.54	12	0.0	0.0		74	76	53	62	17	0.9	8.6	24	NW	19	74	4.6	13	10	7	5	0	2	0	0	0	0	0	1016.6
OCT	69.1	49.7	59.4	85	23	40	25	192	25	1.16	0.58	5-6	0.0	0.0		70	74	47	56	27	2.2	9.4	30	NW	27	70	4.4	14	9	8	8	0	2	0	0	0	0	0	1017.6
NOV	59.9	44.4	52.2	76	6	34	29	378	0	2.31	0.89	26-27	3.1	3.1	26-27	71	75	56	62	36	2.1	8.1	26	NW	24	39	6.9	7	6	17	10	1	0	2	0	0	0	0	1020.0
DEC	51.6	34.6	43.1	74	8	22	29	671	0	4.00	0.93	24	T	T	20	63	69	48	54	24	4.3	10.4	40	NW	17	54	5.6	9	10	12	9	0	0	2	0	0	0	13	0	1016.6
YEAR	66.4	49.7	58.1	100	JUL 23	10	JAN 10	4122	1732	39.56	2.41	MAR 25-26	25.9	4.6	JAN 13	69	71	51	57	30	2.1	9.8	35	SW	JAN 26	42	5.9	114	101	150	113	8	26	4	39	6	76	0	1015.8

Normals, Means, And Extremes

Figure 4-2 (Continued)

Month	Temperatures °F: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches: Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity pct.: Hour 01 (Local time)	Hour 07 (Local time)	Hour 13 (Local time)	Hour 19 (Local time)	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F: Max. 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Average station pressure mb. Elev. 69 feet m.s.l.
(a)				37		37					37		37		33		35		33																				
JAN	43.2	27.7	35.6	79	1950	2	1977	911	0	2.82	7.11	1978	0.31	1933	2.19	1976	21.3	1966	13.8	1966	68	68	64	58	10.0	NW	36	NW	1937	49	6.5	8	7	16	11	2	0	5	23	0	1016.7
FEB	45.4	28.8	37.3	82	1948	4	1961	770	0	2.45	5.71	1961	0.42	1978	1.77	1971	19.0	1967	14.4	1958	63	67	51	55	10.4	S	37	SW	1961	53	6.3	8	6	14	8	1	0	2	19	0	1015.8
MAR	55.4	35.2	45.1	89	1945	11	1943	617	0	3.33	7.43	1953	0.64	1945	3.43	1958	17.1	1960	7.9	1960	63	68	49	52	10.9	NW	50	S	1952	56	6.4	8	8	15	11	1	0	1	9	0	1015.6
APR	67.4	42.7	55.4	93	1976	24	1950	265	7	2.86	5.97	1954	0.26	1942	3.08	1970	0.8	1972	0.8	1972	64	67	46	49	10.5	S	36	N	1952	58	6.3	7	9	14	10	0	0	1	1	0	1014.6
MAY	76.6	55.7	66.2	97	1969	34	1947	72	109	3.68	10.69	1953	1.08	1963	4.32	1953	T	1963	T	1963	72	72	51	57	9.3	S	30	NW	1977	58	6.3	7	11	13	11	0	0	0	0	0	1013.8
JUN	84.0	64.8	74.4	101	1952	47	1972	0	286	3.48	11.53	1974	1.21	1970	7.19	1972	0.0		0.0		76	75	52	60	8.8	S	37	NW	1954	64	5.9	8	11	11	9	0	0	1	2	0	0	1012.8
JUL	88.2	69.1	78.7	103	1954	55	1943	0	423	4.12	11.06	1943	0.93	1966	4.69	1970	0.0		0.0		76	75	52	61	8.2	S	34	E	1951	69	5.9	8	12	11	10	0	0	0	0	0	0	1013.7
AUG	86.0	67.0	77.1	100	1959	51	1963	0	375	4.07	14.31	1955	0.55	1962	8.39	1955	0.0		0.0		78	79	54	63	8.0	S	49	NE	1955	63	5.7	10	9	12	9	0	0	0	0	0	0	1013.9
SEP	80.6	61.4	70.6	100	1953	39	1963	14	182	3.08	12.36	1975	0.20	1967	5.31	1975	0.0		0.0		78	80	55	65	8.2	S	36	SE	1952	62	5.5	10	9	11	7	0	0	0	0	0	0	1015.8
OCT	69.6	49.7	59.8	94	1954	29	1969	190	29	2.66	8.18	1962	T	1963	4.98	1955	T	1974	T	1974	75	78	51	62	8.6	SSW	38	SE	1954	60	5.2	12	7	12	7	0	0	0	0	0	0	1015.8
NOV	57.6	38.8	48.0	86	1974	16	1955	510	0	2.90	6.70	1963	0.87	1965	2.65	1971	0.9	1967	0.9	1967	70	73	52	60	9.2	S	30	E	1952	52	6.1	9	8	13	8	0	0	0	0	0	0	1017.3
DEC	45.6	29.3	37.4	75	1948	1	1942	856	0	3.06	8.54	1967	0.22	1955	2.86	1977	16.2	1962	11.4	1957	68	71	56	61	9.5	NW	32	SW	1957	47	6.4	9	6	16	9	1	0	2	17	0	0	1017.1
YR	66.7	47.8	57.3	103	JUL 1954	1	DEC 1942	4211	1419	38.89	14.31	AUG 1953	T	OCT 1963	7.19	JUN 1972	21.3	JAN 1966	14.4	FEB 1958	71	73	52	58	9.3	S	78	SE	OCT 1956	58	6.0	104	103	158	111	5	29	12	37	9	79	0	1015.3

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 106 in July 1930+; lowest temperature -15 in February 1899; maximum monthly precipitation 17.45 in September 1934; maximum precipitation in 24 hours 7.31 in August 1928; maximum monthly snowfall 35.2 in February 1899; maximum snowfall in 24 hours 25.0 in January 1922.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
- Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Figure 4-2
(Continued)

STATION LOCATION

WASHINGTON, D. C.
WASHINGTON NATIONAL AIRPORT

Location	Occupied from	Occupied to	Airline distance and direction from previous location	Latitude North	Longitude West	Elevation above Sea level: Ground at temperature site	Elevation above Ground: Wind instruments	Extreme thermometers	Psychrometer	Teletypechronometer	Tipping bucket rain gage	Weighing rain gage	8" rain gage	Hygrothermometer	Remarks
CITY															
1719 G Street NW	11/1/70	8/15/88		38° 54'	77° 03'	63	67	a44	a44				b51		a - 59' to 3/10/72. b - 64' to 3/10/72.
1744 G Street NW	8/15/88	3/22/89	Across St.	38° 54'	77° 03'	65	57	58	58				51		
2416 M Street NW	3/22/89	3/5/42	3/4 mi. NW	38° 54'	77° 03'	72	c83	d62	d62		e42	42			c - 67' to 10/16/91; 76' to 1/1/06; unknown to 9/1/06; 58' to 1/1/07; 64' to 4/11/07; 74' to 5/8/07. d - 59' to 9/1/06; 44' to 1/1/07; unknown to 4/11/07.
2400 M Street NW	3/5/42	1/1/66	100 ft. N	38° 54'	77° 03'	72	g100	56	56	g55	54	55	53		g - For period 3/30/49 to 9/22/52.
AIRPORT															
Bolling Field Anacostia, D. C.	8/14/29	7/27/31		*38° 54'	77° 00'	*15	-	33	33						* - Approximate values.
Washington-Hoover AP†	7/27/31	6/16/41	2 mi. NW	38° 52'	77° 03'	12	28	5	5						† - Arlington County, Virginia.
Washington National Airport, Terminal Bldg.	6/16/41	8/5/42	1-1/4mi.SSE	38° 51'	77° 03'	14	89	a6	72		3		3		a - Site 1450 ft. NNW of office.
"	8/5/42	1/1/45	None	"	"	14	89	a6	72		3		3		
"	1/1/45	8/1/45	"	"	"	14	93	a6	72		3		3		
"	8/1/45	11/23/45	"	"	"	14	93	64		64	3		3		
"	11/23/45	4/1/46	"	"	"	14	93	72	72		3		3		
"	4/1/46	7/30/46	"	"	"	14	93	64		64	3		3		
"	7/30/46	9/13/46	"	"	"	14	93	74	72		3		3		
"	9/13/46	11/24/46	"	"	"	14	93	a6		a6	3		3		
"	11/24/46	5/1/47	"	"	"	14	93	72	72		3		3		
"	5/1/47	5/15/47	"	"	"	14	93	a6		a6	3		3		
"	5/15/47	5/16/47	"	"	"	14	93	72	72		3		3		
"	5/16/47	8/28/47	"	"	"	14	93	a6		a6	3		3		
"	8/28/47	9/5/47	"	"	"	14	93	72	72		3		3		
"	9/5/47	12/1/47	"	"	"	14	93	a6		a6	3		3		
"	12/1/47	3/21/48	"	"	"	14	93	b6		b6	3		3		
"	3/21/48	2/16/50	"	"	"	14	93	72	72		3		3		b - Site 500 ft. W of office.
"	2/16/50	9/28/50	"	"	"	14	120	72							
"	9/28/50	10/4/51	"	"	"	14	113	72							
"	10/4/51	2/7/52	"	"	"	14	113	64							
"	2/7/52	8/29/52	"	"	"	14	113	b6	b6		3		3		
"	8/29/52	12/30/57	"	"	"	14	*111	b6		b6	3		3		* - 115 ft. to 3/24/53.
"	12/30/57	9/30/59	"	"	"	14	c20	b6		bA	3		3		c - Site 1/2 mi. ESE of office. Wind equipment on tower roof.
"	9/30/59	9/30/60	"	"	"	14	111	b6		b6	3		3		d - Site 3/8 mi. SE of office.
"	9/30/60	8/30/68	"	"	"	14	d20	77	77		3	3	3	d4	
Main Terminal Building Washington National AP	8/30/68	Present	A	38° 51'	77° 02'	10	20	77	77		3	3	3	4	A - Wind equipment and hygrothermometer moved 750 ft. NE.
							£20				e85	e85	e85	£4	e - Relocated in March 1971. f - Moved 800 feet SSE 8/1/75.

Requests for information concerning solar radiation data or instrumentation should be made to the Director, National Climatic Center, Federal Building, Asheville, NC 28801

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Director, National Climatic Center

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TABLE 4-1

SATURATION MIXING RATIO OVER WATER ($\times 10^{-3}$)*

Temperature (°C)	Pressure (mb)							
	1000	850	700	600	500	400	300	200
40	49.81	59.41						
35	37.25	44.27						
30	27.69	32.82	40.29					
25	20.44	24.17	29.59					
20	14.95	17.66	21.56	25.29				
15	10.83	12.78	15.57	18.24				
10	7.762	9.146	11.13	13.02	15.69			
5	5.495	6.471	7.870	9.198	11.07			
0	3.839	4.519	5.492	6.415	7.710			
- 5	2.644	3.112	3.780	4.412	5.300	6.637		
-10	1.794	2.110	2.562	2.990	3.590	4.492		
-15	1.197	1.408	1.700	1.994	2.393	2.993	3.995	
-20	0.785	0.923	1.120	1.306	1.568	1.960	2.615	
-25	0.505	0.594	0.720	0.840	1.008	1.260	1.680	2.523
-30	0.318	0.374	0.454	0.530	0.635	0.794	1.058	1.588
-35	0.196	0.231	0.280	0.327	0.392	0.490	0.653	0.979
-40	0.118	0.139	0.169	0.197	0.236	0.295	0.393	0.589
-45	0.070	0.082	0.099	0.116	0.139	0.173	0.231	0.346
-50	0.040	0.047	0.057	0.066	0.079	0.099	0.132	0.198

*Extracted from Smithsonian Meteorological Tables (Washington, D.C., 1951)

Therefore, H can be determined simply by observing the relative humidity and determining r_s from some suitable reference, or expressed analytically

$$H = 7000 \frac{\text{grains}}{\text{pound}} \times r$$

where $r = (RH(\%)/100\%)r_s$

It is important to note that while the expression for the NO_x emission factor correction is an explicit function of humidity only, that is an implicit function of ambient temperature and pressure through its dependence on the saturation mixing ratio. Care must be exercised in determining r_s to ensure that it is representative of the geographic area for which the emissions estimates are being made. This is particularly true in high altitude areas where atmospheric pressure is relatively low.

The meteorological variable should be chosen to correspond as closely as possible to the conditions existing or presumed to exist during the time period for which the emission inventory is being prepared. The time period of interest is, of course, dictated by the time period for which the pollutant concentrations are to be calculated or by some presumed critical emissions period. For example, if short-term estimates of emissions are to be made, then the LCD, Monthly Summary is used to determine temperature, pressure and relative humidity for the desired time period, e.g., 6:00 to 9:00 a.m. The saturation mixing ratio can then be approximated from Table 4-1.

When making annual emission estimates, the temperature, pressure and relative humidity should be selected from the LCD, Annual Summary with comparative data. The values selected should be the annual values from those given under "Meteorological Data for the Current Year".

Suppose an estimate of the annual NO_x emissions for Washington, D.C. in the year 1978 was desired. In order to determine the humidity correction

factor, "H" must be determined as in Section 4.2. From the annual statistics for 1978, for Washington, see Figure 4-2, the average yearly temperature, pressure and relative humidity are 58.1°F (14.5°C), 1015.8 mb and 62%, respectively. Note that the relative humidity has been averaged over all hours (01, 07, 13 and 19). Linear interpolation could be used in Table 4-1 to determine r_s (saturation mixing ratio) or more detailed tables used. However, given the overall precision in an annual analysis, it is probably sufficient to use the r_s corresponding to 15°C and 1000 mb, 10.8 x 10^{-3} or 0.0108. Then r becomes

$$r = (RH)\ r_s/100\%$$
$$r = (62\%)(0.0108)/100\%$$
$$r = 0.007$$

and

$$H = (7000 \text{ grains/pound})\ r$$
$$= 49.0 \text{ grains of water vapor/pound of dry air}$$

Note that the humidity correction factor for NO_x in MOBILE2, i.e.,

$$C.F. = 1.0 - 0.0047\ (H - 75.0)$$

becomes 1.12 for an H of 49.0. This represents a 12 percent increase in NO_x emissions above the default correction factor.

If short term analyses are to be performed, the temperature and relative humidity for the specific time to be considered are given by the LCD, Monthly Summary under "Observations at 3-hour Intervals". The ambient pressure will be the average station pressure for the day and must be converted from inches of mercury to millibars (mb) (1 inch of mercury equals 33.8622 millibars).

4.3 POTENTIAL UNCERTAINTIES

Uncertainties are introduced into the emissions estimates if the meteorological data are not spacially representative of the area in which the

emissions occur, i.e., differences in urban/rural environments, significant terrian features or the normal stochastic nature of meteorological variables. Also, in the case of annual estimates, the meteorological variables have been averaged over an entire year and, hence, do not reflect the values of those parameters during the daily (cyclic) NO_x emission patterns. Some additional uncertainty could be introduced if one was estimating "normal" or "average" annual emission and a specific year was anomalous in a climatological sense. This problem could be overcome, however, by using the parameter values from the "Normals, Means, and Extremes" portion of the annual LCD.

5. TEMPERATURE

Ambient temperature has an effect on the CO and HC MOBILE2 emission estimates. Because this variable is routinely recorded, its value can be easily determined from readily available meteorological data. The discussion on available data sources, methodology and caveats so parallel that on humidity in Section 4, the reader is referred to that section for detailed treatment of ambient temperature.

6. VEHICLE MILES TRAVELED

Mobile source emissions in an area vary directly with the number of miles vehicles travel within that area and the mix of vehicles traveling on the roads. For instance, if the majority of miles traveled are by trucks, emissions will be higher than if automobiles make up the majority of roadway travel. The following sections discuss the alternative methods available to estimate the number of vehicle-miles-traveled (VMT) for each vehicle classification. This can be used to estimate the fraction of the total VMT per vehicle type and the total VMT in a given locality. Because the available data present urban VMT by state, if a rural area is being analyzed, these data do not apply.

6.1 LIGHT-DUTY VEHICLES

This section describes the techniques available to estimate light duty vehicle-miles-traveled in a locality from national data, and the associated fraction of total urban VMT. The subsequent sections describe the data sources, methodology and associated problems connected with estimating light-duty vehicle VMT. The techniques for estimating total VMT for light-duty vehicles are assumed to apply to light-duty diesel as well as light-duty gasoline vehicles.

6.1.1 Data Sources

Data from the Nationwide Personal Transportation Study (NPTS) are needed to estimate VMT for light-duty-vehicles. The NPTS identifies VMT according to several categories: trip purpose, household income, and place of residence (incorporated/unincorporated). All of these data can be used to estimate VMT in a locality. Another source of data that may be needed, depending on the estimation technique utilized, is the Census of

Population and Housing, Preliminary Population and Housing Unit Counts. In addition, estimates of state or county light-duty vehicle registrations may be required. The county and state registration data can be gathered from state motor vehicle departments. Many local and state agencies calculate VMT for localities and/or counties. For instance, the Atlanta Regional Council calculates VMT for urban areas, the S.E. Michigan Council of Governments estimates light-duty vehicle VMT for seven counties (including Ann Arbor and Detroit), and the S.W. Pennsylvania Regional Planning Commission estimates VMT by vehicle type as does the D.C. Council of Governments. The Chicago Area Transportation Study could be used to approximate VMT by type and the N.Y. State Department of Transportation may also have VMT information. If these data are available for the urban area of interest, they should be used in lieu of the estimation methodology in Section 6.1.2.

6.1.2 Estimation Methodology

The NPTS contains information on vehicle miles per household for households in incorporated areas of various sizes, for households in unincorporated places and for households of different income classes. Most households in a particular locality will travel in that locality when the travel is related to earning a living, family business (i.e., medical and dental, shopping) and education. Social and recreational travel - i.e., vacations, visits and pleasure rides, may not all be within the locality. It is reasonable to assume that of these, vacation travel and pleasure rides will not solely take place in the confines of the locality. Thus, VMT estimates for a local area should exclude these trips. Therefore, VMT can be calculated using the information on trip purpose and location from the NPTS and using data on the number of households from the Census of Population and Housing report (or any other source of information on the number of households in a local area). The calculation using these sources of data can be functionally defined as follows:

$$\text{Light-duty vehicle VMT per day}_p = (HVMT_p - VT_p - PR_p) \times HH \quad (6\text{-}1)$$

where $HVMT_p$ = Vehicle-miles-traveled per household in a place with characteristics p

VT_p = Vacation miles traveled per household in a place with characteristics p

PR_p = Miles traveled for pleasure rides per household in a place with characteristics p

HH = Number of households in the locality

p = Characteristics of the locality, that is p = unincorporated or incorporated with populations:

<5000
5,000-24,999
25,000-49,999
50,000-99,999
100,000-999,999
1,000,000 and over

Table 6-1 lists VMT by household by location by purpose and was taken from the 1972 NPTS. Using these data along with the appropriate data on the number of households in the location in equation (6-1) will yield an estimate of light-duty vehicle VMT per day.

The average annual miles per vehicle increases as the annual income of the household increases (U.S. DOT, 1972,). Therefore, an alternative estimation technique is one which utilizes data on household income and associated travel patterns. This method is preferred over the first method if the locality does not match the unincorporated or incorporated area classifications in Table 6-1. This method, however, should not be preferred over the first method if reliable data on household income are not available. If household income data for a specific locality are available, then equation (6-2) should be used to estimate light-duty vehicle VMT.

TABLE 6-1

DAILY VEHICLE-MILES-TRAVELED PER HOUSEHOLD
PER PURPOSE BY LOCATION

PURPOSE	UNINCORPORATED AREAS	INCORPORATED PLACES WITH POPULATION OF					
		5000	5000-24999	25000-49999	50000-99999	100000-999999	1 million & over
Earning a living	17.6	11.3	12.9	12.8	11.7	10.4	12.6
Family Business	9.1	6.2	7.3	6.0	5.7	4.5	5.5
Educational Civic & Religious	2.5	1.3	1.7	1.3	1.0	1.2	1.3
Social & Recreational:							
Vacations	1.0[1]	1.2[3]	.7[5]	.1[7]	.9[9]	.5[11]	.8[13]
Visits	4.5	3.8	5.2	4.8	5.2	3.4	3.9
Pleasure Rides	1.0[2]	1.2[4]	1.0[6]	1.5[8]	.4[10]	1.0[12]	1.0[14]
Other	5.7	4.7	7.0	5.1	4.5	4.5	5.0
Total Social & Recreational		12.2	10.9	13.9	11.5	11.0	9.4
Other & Unknown	.7	.4	.4	.2	.2	.2	.3
All Purposes	42.1	30.1	40.2	31.8	29.7	25.8	30.4

[1] based on an annual estimation of 345 miles
[2] based on an annual estimation of 384 miles
[3] based on an annual estimation of 432 miles
[4] based on an annual estimation of 428 miles
[5] based on an annual estimation of 265 miles
[6] based on an annual estimation of 377 miles
[7] based on an annual estimation of 57 miles
[8] based on an annual estimation of 538 miles
[9] based on an annual estimation of 314 miles
[10] based on an annual estimation of 159 miles
[11] based on an annual estimation of 193 miles
[12] based on an annual estimation of 357 miles
[13] based on an annual estimation of 554 miles
[14] based on an annual estimation of 453 miles

SOURCE: Nationwide Personal Transportation Study, Household Travel in the United States, Report No. 7, December 1972

$$\text{LDV VMT per day} = \sum_{i=1}^{4} HH_i \times (HVMT_i - VT_i - PR_i) \qquad (6\text{-}2)$$

where: HH_i = number of households in income class i

$HVMT_i$ = VMT per household of income class i

VT_i = miles of vacation travel per household of income class i

PR_i = miles traveled for pleasure rides per household in income class i

i = income class (4 categories)*:

i = 1 → under $7,350
i = 2 → $7,350-$18,370
i = 3 → $18,370-$27,600
i = 4 → $27,600 and over

Table 6-2 summarizes the 1972 VMT by household income data that were needed to carry out the second estimation technique described in this section. To calculate the light-duty vehicle fraction of total VMT, data on total urban VMT for localities are needed. National estimates of urban VMT by state are available. One source is the U.S. Department of Transportation, Highway Statistics 1978. These state data must be scaled down to reflect particular urban VMT. State urban VMT can be scaled to local VMT by calculating the fraction of urban area population to state population; (as presented in the Bureau of the Census, Census of Population and Housing) and assuming that this fraction holds for VMT. Thus, the total VMT for urban area u in state s would be calculated using the following formula:

$$\frac{\text{Population u}}{\text{Population s}} * VMT_s = VMT_u \qquad (6\text{-}3)$$

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* Income levels in the NPTS were expressed in 1970 dollars. Here, income levels have been inflated to 1979 dollars using an inflator of 183.7 when 1970 dollars equal 100. This inflator is from the Statistical Abstract of the United States.

TABLE 6-2

LIGHT-DUTY VEHICLE-MILES-TRAVELED PER HOUSEHOLD
BY INCOME LEVEL, PLACE AND PURPOSE*

Annual Household Income	Earning a Living	Family Business	Educational Civic & Religious	Social** Recreational	Other & Unknown	All Purposes
ALL PLACES:						
under $7350	4.0	3.5	.6	4.6	.2	12.9
$7350-$18370	13.3	6.7	1.6	11.5	.4	33.5
$18370-$27600	21.1	8.6	2.5	15.1	.6	47.9
$27600 and over	31.7	11.4	3.7	19.3	.8	66.9
not reported	16.9	6.0	1.5	12.9	.1	37.4
WEIGHTED TOTAL	14.2	6.6	.16	11.2	.4	34.0
INCORPORATED PLACES:						
under $7350	2.6	2.4	.4	3.6	.1	9.1
$7350-$18370	10.5	5.2	1.1	10.8	.3	27.9
$18370-27600	21.3	7.9	2.2	15.7	.4	47.5
$27600 and over	31.7	11.4	3.7	19.3	.8	66.9
not reported	17.4	5.4	1.4	13.8	.2	38.2
WEIGHTED TOTAL	12.6	5.5	.13	10.7	.3	30.4
UNINCORPORATED PLACES:						
Under $7350	7.2	5.9	1.0	6.7	.5	21.3
$7350-$18370	19.7	10.2	2.9	13.1	.8	46.7
$18370-$27600	20.7	10.2	3.3	13.8	.8	48.8
$27600 and over	34.0	12.8	4.6	22.0	1.2	74.6
not reported	16.0	7.2	1.7	10.9	.1	35.9
WEIGHTED TOTAL	17.7	9.1	2.5	12.2	.7	42.2

TABLE 6-2

LIGHT-DUTY VEHICLE-MILES-TRAVELED PER HOUSEHOLD
BY INCOME LEVEL, PLACE AND PURPOSE
(continued)

* Income levels in the NPTS were expressed in 1970 dollars. Here, income levels have been inflated to 1979 dollars using an inflator of 183.7 when 1970 dollars equal 100. This inflator is from the Statistical Abstract of the United States.

** Social and recreational is not broken down by purpose for all four income levels, but it is for the lowest and highest income level. For incomes below $7,350 per year, pleasure rides account for .6 VMT/day and vacations account for .07 VMT/day. For incomes of $27,600 per year and over, pleasure rides account for 1.4 VMT/day and vacations account for 1.8 VMT/day. It can be assumed that for for incomes of $7,350-27,600 per day, the rate for both pleasure rides and vacations is approximately equal to 1 VMT per household per day each.

SOURCE: Nationwide Personal Transportation Study, Household Travel in the United States: Report No. 7, Dec 1972.

where VMT_s = urban VMT in state s

VMT_u = VMT in urban area u

Hence, the fraction of total urban area VMT attributable to automobiles would be calculated from:

$$\% \text{ LDV VMT} = \frac{\text{LDV VMT}}{VMT_u} \qquad (6\text{-}4)$$

where: % LDV VMT = fraction of VMT due to light-duty vehicles

VMT_u = VMT in an urban area u

LDV VMT = VMT by light-duty vehicles

Total urban VMT by state for 1977 is presented in Table 6-3.

An alternative weighting factor that can be applied to state urban VMT to apportion it to localities is shown in equation (6-4). It utilizes state vehicle registration data and locality (county) vehicle registration data.

$$\frac{\text{Total Vehicle Registrations}_u}{\text{Total Vehicle Registrations}_s} \times VMT_s = VMT_u \qquad (6\text{-}5)$$

where: s = state

u = urban area (locality)

VMT_s = total urban travel in state s

VMT_u = total VMT in urban area u

The estimates of VMT_u from equation (6-5) can be used in equation (6-4) instead of the value calculated from equation (6-3). It should be noted, however, that the assumption taken in equation (6-5) is that the average travel per vehicle in any area in the state is equal to the average travel per vehicle in a specific locality (urban area).

TABLE 6-3

URBAN VEHICLE MILES OF TRAVEL, 1978
(in millions)

State	Urban VMT	State	Urban VMT
Alabama	13826	Nebraska	4884
Alaska	1008	Nevada	2691
Arizona	10223	New Hampshire	2159
Arkansas	5309	New Jersey	39270
California	116828	New Mexico	4682
Colorado	10401	New York	50622
Connecticut	14206	North Carolina	16813
Delaware	2146	North Dakota	1118
Florida	46763	Ohio	40584
Georgia	17849	Oklahoma	12489
Hawaii	2899	Oregon	7812
Idaho	2864	Pennsylvania	40588
Illinois	43799	Rhode Island	4720
Indiana	23115	South Carolina	7233
Iowa	6634	South Dakota	1155
Kansas	6951	Tennessee	16816
Kentucky	11638	Texas	64271
Louisiana	8919	Utah	5035
Maine	2329	Vermont	540
Maryland	17055	Virginia	19018
Massachusetts	28395	Washington	17856
Michigan	44178	West Virginia	3543
Minnesota	13297	Wisconsin	15556
Mississippi	5352	Wyoming	999
Missouri	17457	District of Columbia	3549
Montana	1446		

SOURCE: U.S. Department of Transportation, Federal Highway Administration Highway Statistics, 1978.

6.1.3 Possible Problems Associated with the Above Techniques

The assumption that all recreation travel and pleasure ride travel is not within the urban area could be a source of error (Total VMT could be underestimated). Also, automobile travel by households not residing in the urban area is not accounted for in the above methodologies. In order to correct for this, the user of MOBILE2 can assume that the pleasure rides and vacation trips not taken within the locality account for the travel from households outside the area and thus these amounts should not be subtracted as suggested in equations (6-1) and (6-2).

These methods also assume that there are data on the number of households in a locality. If the number must be approximated, the accuracy of the techniques will decrease. In addition, the data on the number of households listed in the census may not coincide with the urban area.

The assumption in equation (6-3) that the VMT in an urban area is equal to the urban VMT in the state multiplied by the ratio of urban population to state population may render the estimates of fractional VMT by LDV inaccurate. Therefore, if total urban area VMT figures are available, they should be used in place of the estimated figures. In addition, the assumptions taken to arrive at the apportioning factor described in equation (6-5) may bias the VMT estimates since the average VMT per vehicle in an urban area will probably be different than the statewide averages of urban VMT per vehicle; thus urban area VMT will be overestimated if it is less than the statewide average, and underestimated if the average urban VMT per vehicle is greater than the statewide average. Also, the registration data by locality, as estimated from county registration data may not be accurate, which could further bias the VMT estimates if VMT_u calculated from equation (6-5) is used in Equation (6-4).

6.2 LIGHT AND HEAVY-DUTY TRUCKS

The subsequent sections describe the methodology for estimating truck-miles traveled for each truck classification, the data sources required to estimate truck-miles traveled, and the possible problems associated with the estimation procedure.

6.2.1 Data Sources

The sources of data required to approximate truck-miles traveled using the estimation technique described in Section 6.2.2 are the 1979 MVMA Vehicle Facts and Figures report and the Bureau of the Census, Census of Population and Housing (1970) report. State Motor Vehicle Departments must also be contacted for state and county truck registration data. Data on the fraction of total VMT in an area attributable to trucks may be available on a local or state level. Some of the agencies listed in Section 6.1.1 disaggregate VMT by county (counties) by truck classification. Others may not classify trucks by GVW class, but may list VMT for one category of truck or for truck classifications other than those listed in Table 1-1. Truck VMT data for a specific locality are preferred over the estimates resulting from using national data and the methodology described in Section 6.2.2.

6.2.2 Estimation Methodology

The MVMA annual report (MVMA, 1979) reports that trucks traveled 153,350 million urban miles in 1977, out of 821,971 million urban miles traveled nationally by all vehicles. Thus, urban truck-miles traveled accounts for 18.66 percent of total urban travel. Table 6-4 lists truck urban travel on the state level, and is based on the assumption that 18.66% of state urban VMT is attributable to trucks.

In order to account for truck emissions, urban truck VMT must be calculated for each truck classification. Table 6-5 lists the percentage of truck urban VMT attributable to each truck classification nationwide.

TABLE 6-4

TOTAL URBAN* TRUCK TRAVEL BY STATE 1977
(in millions)

State	Urban** Truck-Miles Traveled	State	Urban Truck-Miles Traveled
Alabama	2,377	Montana	308
Alaska	220	Nebraska	859
Arizona	1,748	Nevada	455
Arkansas	921	New Hampshire	387
California	20,331	New Jersey	7,184
Colorado	1,800	New Mexico	845
Connecticut	2,698	New York	8,985
Delaware	383	North Carolina	2,914
Florida	8,178	North Dakota	193
Georgia	3,119	Ohio	7,404
Hawaii	527	Oklahoma	2,325
Idaho	424	Oregon	1,401
Illinois	8,430	Pennsylvania	7,270
Indiana	4,292	Rhode Island	863
Iowa	1,603	South Carolina	1,399
Kansas	1,279	South Dakota	199
Kentucky	2,135	Tennessee	3,397
Louisiana	1,624	Texas	10,622
Maine	426	Utah	854
Maryland	2,984	Vermont	94
Massachusetts	5,110	Virginia	3,407
Michigan	7,607	Washington	3,113
Minnesota	2,501	West Virginia	650
Mississippi	959	Wisconsin	2,697
Missouri	3,228	Wyoming	158
District of Columbia	610		
TOTAL			153,497

* Urban travel consists of travel on all roads and streets in places of 5,000 or greater population (MVMA, 1979)

** Based on 1977 percentages of truck travel to total urban travel

SOURCE: 1979 MVMA, Motor Vehicle Facts and Figures.

TABLE 6-5

PERCENTAGE OF URBAN TRUCK TRAVEL BY TRUCK CLASSIFICATION
(1977)

Truck Classification	Percentage of Total Urban Truck Travel
Light Duty Gas Truck 1	47.64%
Light Duty Gas Truck 2	28.66
Heavy Duty Gas Vehicle	16.70
Light Duty Diesel Truck	.02
Heavy Duty Diesel Vehicle	6.98
	100.00

Source: Extracted from MVMA Facts and Figures, 1979.

Tables 6-4 and 6-5 can be used to estimate urban VMT by classification on a state level. However, truck VMT on a specific urban (local) level must be calculated. Therefore, the total urban VMT by state must be apportioned to individual localities. Two apportioning factors are available to the user of MOBILE2.

The first factor utilizes registration data by county and state from state motor vehicle departments. Assuming that the statewide urban travel per truck is equal to urban (local) travel per truck, the ratio of local urban truck miles traveled to state urban truck miles traveled should be equal to the ratio of trucks registered in a local (urban) area to trucks registered in the state. Mathematically, this relationship is described as follows:

$$\text{Trucks}_s \times \frac{\text{statewide urban VMT}}{\text{truck}} = \text{Total state urban truck miles traveled}$$

$$\text{Trucks}_l \times \frac{\text{local urban VMT}}{\text{truck}} = \text{Total local urban truck miles traveled}$$

where: Trucks_s = Number of trucks registered in the state

Trucks_l = Number of trucks registered in the local area

It follows that:

$$\frac{\text{Total local urban truck miles traveled}}{\text{Total state urban truck miles traveled}} = \frac{\text{Trucks}_l}{\text{Trucks}_s} \qquad (6\text{-}6)$$

since the urban travel per truck is assumed constant on state and local levels. Thus, the first apportioning factor is defined as the ratio of the total number of trucks registered in locality l to the total number of trucks registered in state s.

The alternative apportioning factor uses population data from the Bureau of Census. This factor is derived from the following logic:

$$\frac{\text{Trucks}_1}{\text{Trucks}_s} = \frac{\text{population}_1 \times \frac{\text{trucks}}{\text{population}}}{\text{population}_s \times \frac{\text{trucks}}{\text{population}}} = \frac{\text{population}_1}{\text{population}_s} \qquad (6\text{-}7)$$

where: Population_1 = Population in the local area

Population_s = Population in the state

Assuming that the number of trucks per person is the same for states and localities within states, and that the correct factor is $\text{truck}_1/\text{truck}_s$, an alternate apportioning factor of $\text{population}_1/\text{population}_s$ can be used. Both of these factors are valid under different assumptions; since the values will differ, either can be utilized to calculate truck-miles traveled. The difficulties associated with each factor will be discussed in Section 6.2.3.

The following equation utilizes the data presented in Tables 6-5 and 6-6, and one of the two potential apportioning factors to calculate truck miles traveled in an urban area:

$$TMT_{c1} = TTUT_s \times AF \times \%TUT_c \qquad (6\text{-}8)$$

where: TMT_{c1} = truck-miles traveled for truck classification c in locality 1

$TTUT_s$ = total truck urban travel in state s

AF = apportioning factor (from equation (6-6) or (6-7)

$\%TUT_c$ = percentage of truck urban travel attributable to truck class c (from Table 6-5)

1 = locality, where 1 is a subset of s

The data on total urban travel in a state and percentage of truck travel in each truck classification are based on 1977 values. Therefore, growth rates must be applied to reflect current and future truck-miles traveled. If data on truck-miles-traveled are available on a local

level, but the truck classes are not similar to those listed in Table 1-1, these local estimates should still be used and the percentages in Table 6-5 should be applied to local VMT to approximate urban VMT by truck classification.

6.2.3 Possible Problems Associated with the Estimation Technique

The assumption made in developing the first apportioning factor--that the state average of urban travel per truck is equal to the local average

$$\frac{\text{total state truck urban travel}}{\text{(total number of trucks in state}} = \frac{\text{total local truck travel}}{\text{total number of trucks in locality}}$$

may not be valid in all localities. This would make the apportioning factor $trucks_l/trucks_s$ incorrect and in turn bias the truck-miles traveled estimates. Larger cities with high levels of trucking activities will contribute a larger portion of urban truck miles traveled than smaller urban areas. Therefore, in many instances, the statewide average urban travel per truck will be smaller than the average in the urban area, producing smaller than actual truck VMT estimates. Alternatively, when an urban area is small and does not have large trucking facilities, the state average will be greater than the urban average and the bias will be towards overestimating truck VMT.

The second apportioning factor assumes that the ratio of the number of local to state trucks is valid but uses a proxy for that variable. The proxy assumes that the number of trucks per person does not vary within a state. These assumptions can also bias the calculation of truck miles traveled. In addition, Table 6-5 is based on the 1977 distributions, and these travel distributions may change over time; thus the user should try to calculate local truck travel using current local data if they are available.

The level of difficulty associated with this technique can vary. If the user of MOBILE2 can rely on the estimates generated from equation (6-8)

(using an apportioning factor) the level of difficulty should be low; however, if the user decides to gather local data, the level of difficulty will increase.

6.3 MOTORCYCLES

The subsequent sections identify the data sources needed to estimate motorcycle-miles traveled and the fraction of total VMT attributable to motorcycles, the estimation technique and the possible problems associated with the estimation methodology.

6.3.1 Data Sources

The data on motorcycle registrations in a locality, as recorded by State Motor Vehicle Departments (by county) are needed to estimate motorcycle-miles traveled and the fraction of total VMT. In addition, data from the Motorcycle Industry Council, Inc., 1979 Motorcycle Statistical Annual are needed to estimate motorcycle-miles traveled. The Motorcycle Industry Council, Inc. publishes this report each year, thus the most recent annual should be used when estimating motorcycle-miles traveled. The discussion on estimation techniques contains data from the 1979 report. The types of state or local agencies that may estimate VMT for motorcycles are listed in Section 6.1.1. These agencies should be contacted for information before the technique described in the following section is utilized.

The 1979 Motorcycle Statistical Annual lists 1978 momentary miles per year and 1978 accumulated miles per year. The momentary mileage concept is useful in determining motorcycle-miles traveled. The average momentary mileage figures are not dependent upon the mileage accumulated over previous years, but are dependent on the mileage accumulated in a particular year according to vehicle age and the concept that annual mileage decreases as the motorcycle becomes older. Average momentary mileage

should not be confused with average accumulated miles per year. The following example illustrates the difference using a theoretical sample of five motorcycles:

Model Year	ANNUAL MILEAGE BY CALENDAR YEAR					ACCUMULATED MILEAGE	
	1974	1975	1976	1977	1978	Total	Average
1974	3400	2500	2000	1500	1000	10400	2080
1975		3400	2500	2000	1500	8400	2350
1976			3400	2500	2000	7900	2630
1977				3400	2500	5900	2950
1978					3400	3400	3400
Total Mileage					10400		13410
Momentary miles per year					2080		
Accumulated miles per year							2682

The 1978 momentary miles per year for registered motorcycles calculated from a large sample is 1821 miles.* It is estimated that 78% of the 1821 miles driven per year are on public roads and the remaining 22% are off-public road travel.** Therefore, the motorcycle vehicle miles traveled estimates should be adjusted to reflect this estimation. Therefore, the motorcycle-miles traveled in a locality on public roads is equal to:

$$MMT_l = 1423 \times TMR_l \qquad (6\text{-}9)$$

where: MMT_l = motorcycle-miles traveled in locality l

TMR_l = total motorcycle registrations in locality l

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* Based on 5.1 million registered motorcycles, 62% on-highway cycles and 38% dual purpose motorcycles.

** 87% of the miles driven by on-highway motorcycles are on public roads, and 45% of the miles driven by dual purpose motorcycles are on public roads.

The method for determining total VMT in a locality is discussed in Section 6.1.2. Thus, the fraction of VMT that motorcycles comprise can be calculated by using the following formula:

$$\%MMT = \frac{MMT}{VMT_u} \qquad (6\text{-}10)$$

where: %MMT = fraction of VMT due to motorcyles

MMT = motorcycle-miles driven (calculated from equation (6-9)

VMT_u = vehicle-miles traveled in urban area u (calculated from Section 6.1.2)

The total VMT estimates in urban area u were calculated using 1977 data. Therefore, these data must be grown to present VMT for the current and future years.

6.3.3 Possible Problems Associated with the Estimation Methodology

The momentary miles per year data are based on national estimates, therefore, the distribution may vary for different areas of the country. If more specific averages are available, these should be used instead of the national estimates.

The above techniques imply that only motorcycles registered in a locality travel in that locality (all motorcycle-miles traveled take place within the confines of the locality). This is not necessarily true and this assumption will bias the motorcycle-miles traveled estimates somewhat. Nevertheless, there are no easy methods to correct for this; however, the user should be aware of the uncertainties caused by this assumption. It may be true that for all motorcycles registered in locality 1 traveling outside of locality 1, there is an equal number of motorcycles not registered in locality 1 traveling within locality 1. If this assumption holds, then the estimate of motorcycle-miles traveled fractions (as a fraction of total VMT) will probably be accurate. In

addition, if local areas do not coincide with county areas, (the method by which registration data are recorded), the estimates of motorcycle registrations in a locality will be inaccurate, which will bias the VMT estimate in equation (6-9).

The methodology described in Section 6.3.2 is straightforward and should not be difficult to understand or update. However, if local data are available for motorcycle miles traveled and for on road travel, these should be used instead of the national estimates mentioned in this section.

REFERENCES FOR SECTION 6

Motorcycle Industry Council, Inc. 1979. Motorcycle Statistical Annual. Newport Beach, CA.

Motor Vehicle Manufacturers Association. 1979. Motor Vehicle Facts and Figures. Detroit, MI.

U.S. Department of Commerce. 1970. Census of Population and Housing. Bureau of the Census. Washington, DC.

U.S. Department of Transportation. April 1972. Nationwide Personal Transportation Study. Report Nos. 2 and 7. Federal Highway Administration. Washington, DC.

U.S. Department of Transportation. 1978. Highway Statistics. Federal Highway Administration. Washington, DC.

7. TRIPS PER DAY

The number of vehicle trips per day per vehicle type is an important factor in determining mobile source emissions. Since truck emissions are generally higher than light duty vehicle emissions per mile of travel, it is important to distinguish between the two when estimating the number of vehicle trips. Therefore, the following sections will present methods for estimating the number of vehicle trips per day for each vehicle classification. For the purpose of this report, trips are defined as one-way vehicle travel between places that are at least one block apart.

The total number of trips per day for all classes of vehicles in a locality is the sum of the total trip per day data estimated for each vehicle type using the methodologies outlined in the remaining sections.

7.1 LIGHT-DUTY VEHICLES

The following subsections describe the methods available to estimate vehicle trips per day from national data for automobiles. The methods for trucks and motorcycles will be discussed separately. Data sources will be discussed first, the methodological approach second, and the potential problems associated with the approach third. The number of trips per day for gasoline and diesel-powered light-duty vehicles are assumed to be the same.

7.1.1 Data Sources

Only two national sources of data are needed to estimate automobile trips per day. The Nationwide Personal Transportation Study (NPTS) describes vehicle trips per day by type of area - incorporated/unincorporated by income level and by trip purpose. The descriptions of vehicle

trips by type of area are the most relevant data since most urban areas fall into one of the incorporated area population categories or into the unincorporated category.

The second source required is the Bureau of the Census, Census of Population and Housing. Various local and state agencies compile information on vehicle trips. Many of these agencies conduct surveys within their local jurisdiction or statewide to ascertain the trip patterns within the locality or State. Trip information is compiled from data which is generated by interviewing a sample of households within the locality or state. Regional Planning Commissions typically conduct home interview surveys to collect trip data. These agencies within the specific locality should be contacted first for such information. Other sources of trip information may be available from Regional Councils, Transportation Development Planning Programs, Councils of Government, State and Local Highway Administrations and State Departments of Transportation. Many of the possible sources of information listed above may only have household trip data; thus, these data can only be used to estimate light-duty vehicle and motorcycle trips per day. Truck trip data may be scarce, and when available, the trucks may not be classified as they are in Table 1-1.

7.1.2 Estimation Methodology

The 1972 NPTS describes household travel in the United States. Household travel is described on the basis of trips per day by trip purpose. Area population and household income light-duty vehicle trips per day in localities can be estimated using the data on household travel by area population. Area population in the NPTS is broken into six categories for incorporated places, and one general category for unincorporated places. It should be noted that urban areas can consist of one or more incorporated/unincorporated area; therefore the total population of the urban area should be matched up to the population categories listed in

the NPTS. For example, if the urban area population is split between unincorporated and incorporated areas, then travel data on both unincorporated and incorporated areas should be utilized in estimating light duty vehicle trips per day. Estimates of household trips per day are shown in Table 7-1 for six area population classes and for unincorporated areas. The total number of trips per day in a locality of a certain size can be calculated by multiplying the number of households in a locality (as estimated in the Bureau of the Census Population and Housing Statistics report) by the number of trips per day estimated in the NPTS for a place of the same size characteristics as the locality.

Data on household travel by income class are also presented in the NPTS. However, these data can be utilized only if information on the approximate income distribution of the households in the area is available. If the income distributions can be estimated, then the vehicle trips per day by automobiles can be calculated by multiplying the number of trips per day per income class by the number of households in the income class. Mathematically, this is expressed as follows:

$$\text{Number of Automobile Trips per Day} = \sum_{y=i}^{4} NT_y \times NH_y \qquad (7\text{-}1)$$

where NT_y = number of daily household trips taken by income class Y

NH_y = number of households in income class Y

The number of household trips per day per income class estimated from the 1972 NPTS is shown in Table 7-2.

The major assumption made in describing the above estimation techniques is that the households in a locality comprise the total travel in the locality. This assumption is probably incorrect to a certain degree; however, the average trip length in miles is 8.9 miles, (U.S. DOT, 1972)

TABLE 7-1

TRIP RATE PER HOUSEHOLDS BY
LOCATION & POPULATION

	TRIP RATE PER HOUSEHOLD	
	Annual	Daily*
Unincorporated Areas	1568	4.3
Incorporated Areas with population of:		
<5,000	1056	2.9
5,000-24,999	1870	5.1
25,000-49,999	1479	4.1
50,000-99,999	1344	3.7
100,000-999,999	1226	3.4
1,000,000 and over	700	1.9
Avg of all Incorporated Places	1321	3.6

* Daily rate is derived from the annual rate, assuming travel occurs 365 days per year.

SOURCE: Nationwide Personal Transportation Study, Household Travel In The United States, Report No. 7, December 1972.

TABLE 7-2

TRIP RATE PER HOUSEHOLD
BY INCOME

Annual Household Income (1979$)	Trip Rate per Household		
	All Places	Incorporated Places	Unincorporated Places
Under $7350	1.6	1.3	2.2
$7350-$18,370	3.9	3.5	5.0
$18,370-$27,600	5.3	5.4	5.1
$27,600 and over	6.9	7.1	6.5

SOURCE: Nationwide Personal Transportation Study, Household Travel in the United States, Report No. 7, December 1972

well within the confines of most urban areas. It is conceivable that automobile trips made out of the local area by households within the locality counter the effect of households in the urban area traveling outside the area. Thus, the error introduced by the above assumption should be negligible.

7.1.3 Problems Associated with the Estimation Techniques

As mentioned above, the methodology is based primarily on the assumption that total light-duty vehicle trips in an urban area are approximately equal to the total number of light-duty vehicle trips made by households located in the area. This may introduce more error than the technique assumes. Furthermore, large urban areas may be comprised of many incorporated and unincorporated areas, rendering population characteristics difficult to categorize. In this case, the alternative method for estimating light duty vehicle trips per day is useful. However, data on income may be unavailable, and available data on income levels and households may not be accurate. If data are available, the above methods of estimation should not be difficult to use.

7.2 LIGHT AND HEAVY-DUTY TRUCKS

The following sections discuss the various methods available to estimate truck trips per day. The estimation technique for light-duty trucks (LDGT1, LDGT2, LDDT) is different than that suggested for heavy duty trucks. Thus Section 7.2.1 and its subsections will describe the data sources, estimation technique and problems associated with the methodology for light-duty trucks; and Section 7.2.2 and its subsections will identify the data sources, the estimation techniques and associated problems for heavy duty vehicles.

Several local agencies may be able to provide information on truck trips and truck registration per day for light or heavy-duty trucks or both. Local agencies should be contacted before either of the estimation

techniques outlined below are initiated. Some possible types of agencies that should be contacted are Departments of State, Councils of Government, Regional Planning Commissions, Regional Councils, Transportation Planning Programs and State Departments of Transportation.

7.2.1 Light-Duty Truck Trips per Day

The following subsections describe estimation techniques that can be used to approximate the number of personal trips - work related trips, family errand trips, educational trips and social and recreational trips, that are made by light-duty trucks.

7.2.1.1 Data Sources

The MVMA, 1979 Motor Vehicle Facts and Figures report compiles a limited amount of information on personal trips by mode that can be used for the purpose of this report. In order to estimate light-duty truck trips per day for a particular locality, the U.S. Department of Transportation Highway Statistics report will be required, as well as registration data from State Departments of Motor Vehicles.

7.2.1.2 Estimation Techniques

The MVMA reports that the number of person trips per year using light-duty trucks is 8718 million. According to information on person trips and household trips presented in the MVMA, the ratio of person trips to household trips is 1.84 to 1. Thus, the annual number of household trips taken by personal light-duty trucks in the United States is approximately equal to 4738 million. Table 7-3 lists the total number of households with trucks available in the U.S. and for regions and places of residence within the U.S. These data and the total U.S. trip data can be used to apportion total light-duty truck trips in the U.S. to regions and places of residence. The following equation can be used to apportion the trips. A sample calculation using equation (7-2) is shown in Table 7-4.

TABLE 7-3

HOUSEHOLDS WITH TRUCKS AVAILABLE
(in thousands)

		Residence			
		Inside SMSA's			
Trucks	Total U.S.	In Central Cities	Outside Central Cities	Total SMSA's	Outside SMSA's
1	14579	2339	4954	7292	7301
2	1554	183	468	652	888
Total	16133	2522	5422	7944	8189

		Region*			
Trucks	Total U.S.	Northeast	North Central	South	West
1	14579	1572	3806	5769	3456
2	1554	131	393	545	461
Total	16133	1703	4199	6314	3917

* Northeast = Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania

North Central = Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas, Montana, Wisconsin, Michigan, Illinois, Indiana, Ohio, Wyoming, Utah, Colorado

South = DC, Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas

West = California, Nevada, Arizona, Hawaii, Washington, Oregon, Idaho, Alaska

SOURCE: MVMA, 1979.

TABLE 7-4

SAMPLE CALCULATION AND TOTAL TRIPS BY AREA AND PLACE OF RESIDENCE

Sample Calculation:

$$\text{Annual Trips in Central Cities} = 4738 \times 10^6 \times \frac{2522}{16133} = 741 \times 10^6$$

Total Annual Trips

(mode of travel = light duty trucks)

Place		Area	
Total SMSA's:	2333×10^6	North East	500×10^6
Central Cities:	741×10^6	North Central	1223×10^6
Not in Central Cities:	1592×10^6	South	1864×10^6
Outside SMSA's:	2405×10^6	West	1151×10^6

$$TT_R = TUST \times \frac{TOH_R}{USTOH} \qquad (7\text{-}2)$$

where: TT_R = total trips apportioned to type of residence R, or region of residence R

$TUST$ = total U.S. Trips (in this case 4738×10^6)

TOH_R = number of light duty truck owning households in place R

$USTOH$ = total number of light-duty truck owning households in the U.S.

The major assumption taken when using Equation (7-2) is that the number of trips per household for all areas is constant. The possible problems associated with this assumption will be discussed in Section 7.2.1.3. Furthermore, the relationship expressed in Equation (7-2) does not account for trip making differences between households owning one or two light-duty trucks. If information on automobile trips per one and two automobile owning households were to be used for light duty truck trips, the $TOH_R/USTOH$ ratio would not be changed significantly (less than 1%) for any of the regions and residences listed in Table 7-3. Therefore, one and two light-duty truck owning households are summed for the U.S. and for the areas listed in Table 7-3 to get total truck owning households.

The annual trip data as calculated from Equation (7-2) must be apportioned to individual localities and must be adjusted to reflect daily trips. Assuming that the percentage of total trucks registered which are light-duty is the same regionally and locally, the apportioning factor to be used to apportion regional trips to local trips is:

$$\frac{\text{Total truck registrations in locality}_L}{\text{Total truck registrations in region}_R} = \frac{TTR_L}{TTR_R} \qquad (7\text{-}3)$$

Thus, the final equation that should be used to estimate light-duty truck trips per day in a locality (assuming 365 trip days per year) is:

$$LDTTD_L = (TT_R \times \frac{TTR_L}{TTR_R})/365 \qquad (7\text{-}4)$$

where: $LDTTD_L$ = total light duty truck trips per day in locality L

TT_R = total trips in region R (L is a subset of R) calculated from Equation (7-2)

$\frac{TTR_L}{TTR_R}$ = locality apportioning factor (Equation (7-3))

Total truck registration data for regions can be extracted from the U.S. Department of Transportation, Highway Statistics report. Motor vehicle registrations for trucks are listed by state in this report, hence, to arrive at regional figures, the truck registrations by states within the region should be added to determine regional truck registrations. Table 7-5 lists truck registrations by region for 1978. To arrive at trip per day data by light-duty truck class (LDGT1, LDGT2, LDDT), the fractional registration data calculated in Section 3.2 should be used to apportion total light-duty truck trips in a locality to the three different truck types. If state Motor Vehicle Departments have data on registrations classified by light-duty truck type, these should be used instead of the estimates derived from Section 3.2. In equation form this is expressed as follows:

$$TTD_{L,T} = LDTTD_L \times \%T \qquad (7\text{-}5)$$

where: $TTD_{L,T}$ = truck trips per day in locality L, truck type T

T = LDGT1, LDGT2, LDDT

$LDTTD_L$ = light-duty truck trips per day in locality L (from equation (7-4))

%T = % of total light-duty truck registrations in locality L that are light-duty truck type T (can be extracted from Section 3.2 by summing registrations by age by vehicle type and dividing this sum by total LDT registrations)

TABLE 7-5

TRUCK REGISTRATIONS BY REGION
1978

Northeast	North Central	South	West
3,408,140	10,256,310	10,807,583	7,230,571

SOURCE: U.S. Department of Transporation, 1978 Highway Statistics

If the locality matches a particular SMSA, and registration data are available for all SMSAs, the household information provided in Table 7-3 by SMSA can be used to apportion light duty truck trips per day to localities.

The data supplied herein can be used to approximate light duty truck trips per day assuming that registration patterns in 1978 and truck owning household ratios in 1976 have not changed significantly in the interim. However, when updated information on trips, registrations and truck owning households becomes available, these data should be used, instead of those presented in Table 7-3, 7-4, and 7-5.

7.2.1.3 Problems Associated with the Above Estimation Methodology

The assumption in Equation (7-2) that the number of truck trips per truck owning household is constant across regions may lead to biases in the total trips by region estimates. However, trip data are not available by region, and since the number of truck trips per household are averages, the possible biases resulting from using equation (7-2) should not significantly affect the MOBILE2 estimates. The assumption that the light duty truck percentage of total truck registrations in a region is the same for a locality within the region is an additional source of uncertainty. Therefore, if data on the number of light-duty truck registrations for the region and locality are available, these data should be used in place of total truck registration data.

Light-duty trucks may or may not be used everyday, therefore the trip per day data, using 365 trip days per year as a base, could bias the trip estimates downward. The MOBILE2 user can change the number of trip days per year assumption as needed. The final factor used in equation (7-5) which apportions total light duty truck trips to each of the three light-duty truck classes is based on the assumption that each truck type makes an equal number of trips per day. Again, this assumption will

tend to bias the trip estimates, but data are not available to apportion the trips more accurately. The MOBILE2 user should be aware of the weaknesses in the estimation technique described in Section 7.2.1.2; the user should also exhaust all other sources of data that could more accurately reflect light-duty truck trips per day before using the data and techniques described here.

7.2.2 Heavy-Duty Vehicle Trips per Day

The following sections identify the data sources required and the estimation methodology and associated problems for estimating heavy-duty vehicle trips per day. Heavy-duty vehicles are classified as HDGVs and HDDVs for the purpose of this report.

7.2.2.1 Data Sources

The August 1978 EPA Technical Report, Transient Cycle Arrangement for Heavy-Duty Engine and Chassis Emission Testing contains data on heavy duty vehicle trips per day. Data on heavy duty vehicle registrations in a locality from State Departments of Motor Vehicles will also be required.

7.2.2.2 Estimation Technique

Average trip per day data per vehicle type are compiled in the Technical Report (France, 1978). These data are based on samples of trucks in both New York City and Los Angeles. Equal weighting was given to each city's data since information was not available to indicate whether N.Y. or L.A. operation is more typical of heavy duty vehicle urban operation. Thus, the trip data contained in the technical report, and in Table 7-6 in this report are considered representative averages of urban heavy-duty vehicle trips per day.

Heavy duty vehicle trips per day can be calculated from the data presented in Table 7-6 and the following equation:

TABLE 7-6

VEHICLE TRIPS PER DAY FOR HEAVY DUTY VEHICLES
BY TYPE

	New York	Los Angeles	Midpoint
HDGV	5.93	7.83	6.88
HDDV	2.92	10.38	6.65
All HDV	7.00	7.00	7.00

SOURCE: U.S. EPA, 1978

$$HDVTD_F = ATD_F \times HDVR_{F,L} \quad (7\text{-}6)$$

where: $HDVTD_F$ = heavy-duty vehicle trips per day, fuel type F

F = gasoline or diesel

ATD_F = average trips per day for heavy-duty vehicles using fuel F

$HDVR_{F,L}$ = heavy duty vehicles, fuel F, registered in locality L

Table 7-6 lists two different trip per day averages (medians) for both HDGVs and HDDVs -- one using the New York sample and one using the Los Angeles sample. The median for all heavy-duty vehicles for both NY and LA is seven. Since equation (7-6) requires average trip per day data per vehicle type, a single number for average trips per day per vehicle type must be estimated. One value that can be used is the midpoint of the New York and Los Angeles values.

7.2.2.3 Possible Problems Associated with the Above Estimation Technique

The heavy duty vehicle trip per day data are calculated from a limited sample size - 138 trucks from Los Angeles and 132 from New York. In addition, these two cities are representative of two diverse areas of the United States. Nevertheless, these data are all that are available, hence they must be relied upon until more in depth studies are performed.

Although the figures provided in Table 7-6 are considered representative of any urban area within the U.S., driving and trip patterns undoubtedly vary between localities; and these variations are not captured in the estimation methodology suggested above. Therefore, the trip per day estimates resulting from using equation (7-6) will be biased. Thus, if heavy-duty vehicle trip per day data are available for either a locality or statewide, they should be used rather than the estimates derived from the above methodology.

The estimation technique described in the above section should not be difficult to implement, especially since registration data are supplied from Section 3.2 and the trip data are provided in Table 7-6.

7.3 MOTORCYCLES

The following sections identify the sources of data required to estimate motorcycle trips per day, the estimation technique and the potential problems associated with the technique.

7.3.1 Data Sources

Data from the Motorcycle Industry Council, Inc., and motorcycle registration data from State Departments of Motor Vehicles by county (to approximate local registration) are needed to estimate motorcycle trips per day. As mentioned in Section 7.1.1, local and State agencies, particularly Regional Planning Commissions, should be contacted for trip information specific to the urban area.

7.3.2 Estimation Methodology

Motorcycle trips are broken down by commuting (work, school) trips and non-commuting trips. Table 7-7 summarizes the commuting/non-commuting trip information. The median number of round-trips to work (out of 20 working days) is ten--which translates into one one-way trip per work-week day, or .7 trips per day (per 7 day week). The Motorcycle Industry Council, Inc., Survey of Motorcycle Ownership, Usage and Maintenance reports that 36 percent of all registered motorcycles are used for commuting to work. Therefore, the number of motorcycle work trips per day is equal to the number of motorcycles, on average, that commute to work (in this case 36 percent of all registered motorcycles) multiplied by the number of work trips taken per day (in this case .7).

Mathematically, this relationship is defined as follows:

TABLE 7-7

MOTORCYCLE TRIPS PER DAY BY PURPOSE

Motorcycle Trip Purpose	Percentage of Total Registered Motorcycles Used for This Purpose	Median Number One Way Trips/Day
Commuting:		
Work	36	.7
School	10	.6
Non-Commuting:	100	1.04
Less than 2 miles one way	37	1.4
Between 2 and 10 miles one way	36	1.0
Greater than 10 miles away	27	.6

SOURCE: The Gallup Organization, Inc. 1975.

$$WCT_L = TMR_L \times .36 \times .7 \quad (7\text{-}7)$$

where: WCT_L = total motorcycle work commuting trips per day in locality L

TMR_L = total number of motorcycle registrations in locality L

0.36 = percentage of motorcycles used for work trips

0.70 = number of work trips taken per day

Among the 10% of motorcycles used to commute to school, the median number of round trips taken to school is eight (out of twenty school days). Spread over a seven day week, the number of school trips per day (one way) is approximately equal to .6. Therefore the number of motorcycle trips per day for school commuting is equal to:

$$SCT_L = TMR_L \times .10 \times .6 \quad (7\text{-}8)$$

where: SCT_L = total motorcycle school commuting trips per day in locality L

TMR_L = total motorcycle registrations in locality L

0.10 = percentage of motorcycles used for school trips

0.60 = number of school trips per day

The total number of school and work related commuting trips must be added to the total number of motorcycle trips taken for purposes other than commuting to arrive at the total number of motorcycle trips per day. From Table 7-7, it can be seen that among all motorcycles, 37% are used to make one or more non-commuting trips per week under two miles distance one way, 36% are used to make one or more non-commuting trips per week of between two and ten miles one way, and 27% are used to make one or more non-commuting trips of ten miles or more one way. The median number of round trips per week for the above three distance categories is 5, 3.6, and 2, respectively. Therefore, the number of trips (one way) per day of two miles or less is 1.4, of between two and

ten miles per day is 1.0, and over ten miles per day is 0.6. (Motorcycle Industry Council, Inc., 1979). Using this information, the number of motorcycle trips per day taken for other than commuting purposes is equal to:

$$NCMT_L = (TMR_L \times .37) \times 1.4 + (TMR_L \times .36) \times 1.0 + (TMR_L \times .27) \times 0.6 \quad (7\text{-}9)$$

where: $NCMT_L$ = non-commuting motorcycle trips in locality L

TMR_L = total motorcycle registrations in locality L

The sum of $WCMT_L$, $SCMT_L$, and $NCMT_L$, from equations (7-7, 8, 9) should be approximately equal to the total motorcycle trips per day, assuming that all of the non-commuting trips originate in the urban area.

This method is not valid in all locations, due to the fact that motorcycle use is seasonal. States in the East, Midwest and West use motorcycles an average of 6 months per year, and states in the South use motorcycles 8 months per year. Hence, the number of trips per day will vary seasonally by region. Table 7-8 lists the nationwide percentage of total motorcycles used by month. Therefore, the total number of trips per day should be apportioned using these percentages. Data on use by month by region are not available, therefore monthly data on a national level must be used to adjust the estimated average number of trips per day.

Therefore, the final formula to be used to estimate the number of motorcycle trips per day in month M is:

$$TMTD_{LM} = (WCT_L + SCT_L + NCMT_L) \times \%U_M \quad (7\text{-}10)$$

where: $TMTD_{LM}$ = total motorcycle trips per day in locality L, month M

WCT_L = work commuter motorcycle trips per day in locality L

TABLE 7-8

NATIONWIDE PERCENTAGE OF MOTORCYCLES REGULARLY RIDDEN ON THE STREET EACH MONTH

Months Regularly Ridden on Streets	Percentage of Total
January	35
February	35
March	47
April	65
May	81
June	86
July	87
August	85
September	80
October	65
November	43
December	36

SOURCE: The Gallup Organization, Inc., 1975.

SCT_L = school commuter motorcycle trips per day in locality L

$NCMT_L$ = non-commuter motorcycle trips per day in locality L

$\%U_M$ = percentage of use in month M

M = month of the year

Alternatively, if the MOBILE2 user wishes to arrive at the typical number of motorcycle trips per day, regardless of the months of ridership, the following equation should be used:

$$TMTD_L = \frac{\sum_{M=1}^{12} (WCT_L + SCT_L + NCMT_L) \times \%U_M}{12} \qquad (7\text{-}11)$$

where: $TMTD_L$ = total motorcycle trips per day in locality L

WCT_L = work commuter motorcycle trips per day in locality L

SCT_L = school commuter motorcycle trips per day in locality L

$NCMT_L$ = non-commuter motorcycle trips per day in locality L

$\%U_M$ = percentage of use in month M

M = month of the year (M = 1-12)

7.3.3 Problems Associated with the Estimation Methodology

The above technique does not account for motorcycle trips originating outside the urban area and assumes that all motorcycle non-commuting trips originate within the urban jurisdiction. These two assumptions should counter balance each other, thus the trip per day approximation should be accurate. Motorcycle trips vary with weather conditions. Rainy, cold days are not conducive to motorcycle use. The effect of weather on motorcycle trip taking is indirectly accounted for in the monthly riding adjustment. However, monthly averages of motorcycle use

percentages do not correct for weather induced riding patterns sufficiently to yield accurate trip approximations on a daily basis. Nevertheless, the monthly data are all that are available and relating weather and trip patterns for motorcycles would be extremely difficult. In addition, this added effort would not guarantee more accurate estimates than the ones produced using the estimation technique described in Section 7.3.2. Also, the motorcycle use percentages in Table 7-8 are based on national data, and will vary across localities. However, as mentioned above, the national monthly data are all that are available. Therefore, until more research is conducted on motorcycle usage, the above estimation technique should be sufficient. As mentioned in Section 7.3.1, local trip data, if available, should be used over the estimates resulting from utilizing the estimation technique described in Section 7.3.2. This technique should not be difficult to utilize, considering that the needed data are in Section 7.3.2, and the Motorcycle Industry Council, Inc. revises this information annually.

REFERENCES FOR SECTION 7

France, C.I., August, 1978. Transient Cycle Arrangement for Heavy-Duty Engine and Chassis Emission Testing. Technical Report. U.S. Environmental Protection Agency. Ann Arbor, MI.

Motorcycle Industry Council, Inc. 1979. Motorcycle Statistical Annual. Newport Beach, CA.

Motor Vehicle Manufacturers Association. 1979. Motor Vehicle Facts and Figures. Detroit, MI.

The Gallup Organization, Inc. January 1975. Survey of Motorcycle Ownership, Usage and Maintenance. Conducted for the Motorcycle Industry Council, Inc. Newport Beach, CA.

U.S. Department of Commerce. 1970. Census of Population and Housing. Bureau of the Census. Washington, DC.

U.S. Department of Transporation. April 1972. Nationwide Personal Transportation Study. Report No. 7. Federal Highway Administration. Washington, DC.

U.S. Department of Transportation. 1978. Highway Statistics. Federal Highway Administration. Washington, DC.

8. VMT PERCENTAGE IN COLD AND HOT STARTS

8.1 LIGHT-DUTY VEHICLES

As measured by the Federal Test Procedure (FTP), the time period when vehicle emissions are highest is the first 505 seconds after engine start-up, when the engine temperature is "cold". A cold engine has a temperature equal to the ambient temperature. With a "cold start", an engine must be supplied with a rich air-fuel ratio in order to sustain combustion until an equilibrium condition is reached. This "rich" operation results in incomplete fuel combustion and high emissions of CO and HC. NO_x emissions are not affected by the cold-start condition because they are products of high combustion temperatures.

Identifying the percentage of VMT in both the cold and hot start modes is of interest. A cold start is defined to be a vehicle start after a long engine-off (or cold soak) period. This period is defined as four hours or more for non-catalyst vehicles, and one hour or more for catalyst vehicles. The differentiation between cold start operation and hot start operation is strictly dependent upon the length of the engine off period. A hot start condition simulates cases where the length of engine off time is short enough that vehicle engine temperatures/emission control systems do not cool down significantly; for example, a hot start situation would not activate the vehicle choke. Emissions are increased during a hot start condition due to the dumping of excess fuel which is stored in the carburetor, evaporative canisters, etc. Thus, emissions following a hot start quickly return to their normal stabilized levels. A hot start is any start after an engine-off period of less than four hours for non-catalyst and one-hour for catalyst-equipped vehicles.

The standard FTP assumptions for cold and hot start percentages are 21 percent and 27 percent, respectively. If emission calculations are desired for scenarios matching the FTP conditions, then no correction is necessary. In situations where the cold and hot start fractions do not match the FTP assumptions, the estimated VMT percentage in each mode should be used in MOBILE2. Methods for estimating these percentages are shown below.

The techniques recommended for estimating hot/cold start VMT fractions for light-duty gasoline-powered vehicles should also apply to light-duty diesels. While the warm-up characteristics of light-duty diesels may differ from those of gasoline vehicles, the same test procedure is used for both, and in the absence of more complete information it is recommended that the same hot/cold start fractions be used for both. Light-duty diesels do not have catalysts. Therefore, if hot/cold start VMT fractions are identified separately for catalyst and non-catalyst vehicles, the non-catalyst estimates should be used for light-duty diesels.

8.1.1 Data Sources

The State of Alabama study entitled The Determination of Vehicular Cold and Hot Operating Fractions for Estimating Highway Emissions (Ellis, Camps, and Treadway, 1978) is the recommended source of data for method 1. Additional information for method 1 can be taken from Determination of Percentages of Vehicles Operating in the Cold Start Mode (Midurski and Castaline, 1977).

No specific sources are recommended for methods 2 and 3.

8.1.2 Method 1 - Using Transportation Planning Data

A recent study (Ellis, Camps, and Treadway, 1978) performed for the Department of Transportation presents three procedures for determining cold and hot operating fractions using data normally generated during

the transportation planning process. These procedures can be used according to the level of detail of the transportation planning data available to the local area performing the analysis. The three procedures are referred to as the Complete Method, the Abbreviated Method, and the Simplified Method. The only information needed to apply the Simplified Method is an estimate of the average trip length of all internal auto trips for the hours of the day being studied. Average trip length is available from the trip distribution data generated during transportation planning using the FHWA Computer Programs for Urban Transportation Planning. (Trip distributions should include terminal times.)

The Abbreviated Method requires data on the average trip length for each trip purpose in the area of interest, and either the fraction of travel represented by each purpose or the number of trips of each purpose. The use of the Complete Method is time consuming and is not recommended unless significant resources are available for this work and the trip-making characteristics of the area in question are significantly different than those in the cities used in the State of Alabama study (Ellis, Camps, and Treadway, 1978). Copies of this study can be obtained from the Office of Environmental Policy, Federal Highway Administration, U.S. Department of Transportation.

8.1.3 Method 2 - Conducting a Motorist Survey

If a microscale analysis is being performed, a quick roadside survey can be designed to ask motorists how long ago they started their engine (time and/or miles) and how long the engine was off prior to start-up. A potential survey design would be to have interviewers query drivers stopped in left-turn lanes. This would make drivers easily accessible and would provide the maximum interview length of any location at an intersection. Both in-person interviews and mail-back questionnaires are feasible.

If regional cold/hot start percentages are needed, a sample of roadways could be surveyed and the results applied to the whole urban area. In this case, care should be taken in choosing a representative sample of roadways.

For both survey approaches, the study should be designed to distinguish the temporal variations in VMT in the cold and hot start percentages.

8.1.4 Method 3 - Using Engine Temperature Measurements

Direct measurement techniques exist which can determine whether a vehicle is in a stabilized emission configuration. These techniques can be difficult to implement due to the need to perform extensive calibration. Some measurement methods require the vehicles to stop for several minutes while other techniques require only a 30 second stop or no stop. Broadly, the measurement techniques can be divided into two types: those which use a thermocouple measurement technique and those which use an infrared measurement technique. Temperature measurements from a number of areas of the vehicle can be fairly well correlated with emissions in a gross sense (that is, emissions stabilized or emissions not stabilized). These areas include: inlet to vehicle radiator, oil pan, catalyst skin, exhaust gas, and difference between vehicle hood and vehicle trunk.

8.1.5 Advantages and Disadvantages of the Estimation Procedures

Method 1 (using transportation planning data) is by far the easiest and least costly of the three methods to implement. Therefore, in terms of both overall ease and potential accuracy of the procedure, the first method would be preferable in most cases. Methods 2 and 3 would only be feasible if a microscale analysis was being performed, and accurate cold/hot start percentages were needed for a small sample of roadways.

Method 1 is not without problems, though. Because transportation planning data are compiled for a purpose different than they are being used

for in Method 1, errors can result. Within the transportation planning process, the trip distributions and the traffic assignments are based largely on theoretical relationships and a synthetic highway network. However, the most important point of uncertainty is that the estimate of cold/hot start percentages is very sensitive to the time-from-trip-origin factor and the relative error in that factor is greatest in the 0 to 3 minute time range. This is crucial because the cold start phase is only 505 seconds long. Therefore, any cold/hot start percentages estimated from Method 1 should be used with caution.

8.2 LIGHT-DUTY TRUCKS

The methods recommended for light-duty vehicles are also assumed to apply for light-duty trucks.

8.3 HEAVY-DUTY TRUCKS

MOBILE2 does not include a correction factor for hot/cold starts for heavy-duty vehicles. Therefore, no information is presented for estimating this variable.

8.4 MOTORCYCLES

The information presented for light-duty vehicles should also be assumed to apply for estimating the fraction of VMT in cold and hot start modes for motorcycles as well. The driving cycle for motorcycles with large engine displacements should be equivalent to that for light-duty vehicles and trucks. In 1978, 83.3% of the on-highway motorcycles in use had an engine displacement of 350 cc's or greater (Motorcycle Industry Council, Inc., 1979). Smaller motorcycles are different in that they do not reach the highest speeds of the Federal Test Procedure. Nevertheless, using the cold and hot start estimates calculated in Section 8.1 for motorcycles appears to be reasonable.

REFERENCES FOR SECTION 8

Ellis, G., Camps, W. T., and Treadway, A. September 1978. The Determination of Vehicular Cold and Hot Operating Fractions for Estimating Highway Emissions. State of Alabama Highway Department. Mongtomery, AL. Prepared for U.S. DOT-FHWA.

Midurski, T. P. and Castaline, A. H. August 1977. Determination of Percentages of Vehicles Operating in the Cold Start Mode. (EPA-450/3-77-023). GCA Corporation. Bedford, MA. Prepared for U.S. EPA-OAQPS.

Motorcycle Industry Council, Inc. 1979. Motorcycle Statistical Annual. Newport Beach, CA.

9. AIR CONDITIONING UNITS

MOBILE2 contains a correction factor for air conditioning usage which accounts for the increase in emissions of HC, CO, and NO_x when vehicle air conditioners are in use. This section presents techniques for estimating the number of vehicles with air conditioning units for light-duty vehicles and light-duty trucks.

9.1 LIGHT-DUTY VEHICLES

The following subsections describe a method by which the number of air conditioning units in the light-duty vehicle population as a percentage of registrations can be estimated. This method utilizes data on nationwide percentages of factory-installed air conditioners by model year. Section 9.1.1 describes the data sources, Section 9.1.2 describes the estimation technique, and Section 9.1.3 points out the advantages and disadvantages of using this method.

9.1.1 Data Sources

Ward's Automotive Yearbook contains information on the number and percentage of U.S. cars with factory installed air conditioners. The MVMA Motor Vehicle Facts and Figures report contains the same information.

9.1.2 Estimation Technique

The most recent Ward's Automotive Yearbook (1979) presents data on the percentage of U.S. cars with factory-installed air conditioners by model year for 1949-1978. While some vehicle owners install air conditioners after a car is purchased, this probably will increase the number of air conditioning units by only a small percentage. Therefore, this procedure assumes that factory-installed equipment accounts for all AC units

in U.S. cars. Table 9-1 shows the percentage of U.S. cars with factory-installed AC units.

The percentage of factory installed ACs in U.S. registered foreign cars is much lower than that of U.S. made cars. Ward's Automotive Yearbook presents data on the percentage of factory-installed AC units for imports, but only post-1974 model year light-duty vehicles have reported data. These numbers are shown in Table 9-1.

Table 9-1 shows how the nationwide percentage of the light-duty vehicle fleet with factory installed air conditioners can be estimated. Basically, the percentage of U.S. cars with AC is multiplied by the U.S. percentage of LDV sales, and the percentage of import cars with AC is multiplied by the import percentage of LDV sales, and the two products are summed. The total fleet AC percentage for pre-1975 LDV's was calculated assuming no imports with AC.

9.1.3 Advantages and Disadvantages of the Estimation Procedure

It is likely that the demand for factory-installed AC units in light-duty vehicles varies by region. Therefore, it is probable that the percentage of light-duty vehicles with AC in Houston is higher than that in Minneapolis. If possible, these regional variations should be taken into account by the user. Using the nationwide percentages in Table 9-1 may result in some error if applied universally.

Because the market share of imports may also vary by region, state/local estimates of these market shares can be used in Table 9-1 in lieu of the percentages listed there.

9.2 AIR CONDITIONING UNITS FOR LIGHT-DUTY TRUCKS

The data sources and estimation technique for determining the percentage of light-duty trucks with AC by model year are identical to those

TABLE 9-1

PERCENTAGE OF LIGHT-DUTY VEHICLES WITH FACTORY INSTALLED AIR CONDITIONING BY MODEL YEAR

Model Year	U.S. Cars* % with AC	U.S. Cars** % of LDV Sales	Imports* % with AC	Imports** % of LDV Sales	Total+ Fleet % with AC
1978	80.8%	83%	30.7%	17%	72%
1977	81.7	81	27.1	19	71
1976	74.0	85	21.3	15	66
1975	72.6	82	19.3	18	63
1974	67.9	84		16	57
1973	72.6	85		15	62
1972	67.5	85		15	57
1971	63.4	85		15	54
1970	60.1	85		15	51
1969	55.3	89		11	49
1968	44.3	89		11	39
1967	38.0	91		9	35
1966	29.3	93		7	27
1965	23.3	94		6	22
1964	17.9	94		6	17
1963	14.1	95		5	13
1962	11.3	95		5	11
1961	8.1	94		6	8
1960	6.9	93		7	6
1959	6.2	90		10	6

* Source: Ward's Automotive Yearbook

** Source: McNutt, Dulla, and Lax, 1979

\+ Data on the percentage of imports with AC for pre-1975 model years was not reported in Ward's Automotive Yearbook. The total fleet AC percentage for pre-1975 LDV's was calculated assuming no imports with AC.

identified for light-duty vehicles in Section 9.1. Table 9-2 lists the percentage of domestic and import light trucks with air conditioning units by model year. Data on the percentage of light trucks with air conditioning are only available for post-1973 domestic and post-1975 imported light trucks.

All of the AC installation percentages listed in Table 9-2 represent all trucks less than 10,000 lb gross vehicle weight.

TABLE 9-2

LIGHT-DUTY TRUCKS WITH FACTORY INSTALLED AIR CONDITIONING
BY MODEL YEAR

Model Year	U.S. Light Trucks* % with AC	U.S. LDT's** % of Sales	Imports* % with AC	Imports** % of Sales	Total Fleet % with AC
1978	41.2%	93.4%	12.5%	6.6%	39.3%
1977	53.2	96.4	10.5	3.6	51.7
1976	33.3	94.1	2.1	5.9	31.5
1975	30.6	88.5		11.5	
1974	29.3	91.6		8.4	
1973		97.3		2.7	
1972		92.5		7.5	
1971		94.6		5.4	
1970		95.2		4.8	

* Source: Ward's Automotive Yearbook

** Source: McNutt, Dulla, and Lax, 1979

REFERENCES FOR SECTION 9

McNutt, B., Dulla, R., and Lax, D. February 1979. "Factors Influencing Automotive Fuel Demand", SAE Technical Paper Series, Congress and Exposition, Detroit, MI.

Motor Vehicle Manufacturers Association. 1979. Motor Vehicle Facts and Figures. Detroit, MI.

Ward's Communications, Inc. 1979. Wards Automotive Yearbook. Detroit, MI.

10. EXTRA LOAD AND TRAILER TOWING TRIPS

This section presents techniques for estimating the number of trips/day per vehicle type that are made with extra loads or towing trailers. Techniques for both light-duty vehicles and light-duty trucks are discussed.

10.1 EXTRA LOADS FOR LIGHT-DUTY VEHICLES

The following subsections describe a method by which the percentage of light-duty vehicles which are operating under an additional 500 pound load can be estimated. Section 10.1.1 describes the data sources, Section 10.1.2 describes the estimation technique, and Section 10.1.3 discusses the advantages and disadvantages of using this method.

10.1.1 Data Sources

The Nationwide Personal Transportation Study (U.S. DOT, 1972) is used to estimate vehicle occupancy by trip purpose.

10.1.2 Estimation Technique

To apply the MOBILE2 vehicle loading correction factors to a specific situation, it is necessary to estimate the percentage of light-duty vehicles which are operating under an additional 500 pound load because they are heavily occupied with people or baggage. It is assumed here that trips with four or more vehicle occupants produce an extra load. Data on automobile occupancy are taken from the NPTS (U.S. DOT, 1972). Table 3 in Report No. 1 of the NPTS shows the distribution of automobile trips by number of occupants for each purpose of travel for SMSA residents. The following percentages were determined from the NPTS:

Trip Purpose	Percentage of Trips With Four or More Occupants
Earning a living	3.3%
Family business	10.1
Educational, civic and religious	22.6
Social and recreational	21.3

These percentages can then be used along with the data in Table 10-1 to estimate the percentage of light-duty vehicle travel occurring under extra load conditions. It is assumed that the percentages are the same for all light-duty vehicle ages. This procedure is shown below for an example city of 75,000 population.

Trip Purpose	Percentage of Trips with 4 or more Occupants	Daily Trips per Household per Purpose	# Daily Trips with 4 or more Occupants
Earning a living	3.3%	1.3	.043
Family business	10.1	1.2	.121
Educational civic and religious	22.6	.3	.068
Social & recreational	21.3	.8	.170
Total		3.6	.402

In this example city, 11.2 percent of the trips taken by light-duty vehicles are estimated to be with extra loads. This percentage was calculated by dividing the number of daily trips with four or more occupants (.402) by the total number of daily trips (3.60).

10.1.3 Advantages and Disadvantages of the Estimation Procedure

The major advantage of the proposed technique is that it is computationally simple and it uses survey data from a large sample of households. However, a nationwide sample of households was used, so no area specific differences are accounted for. The only part of the procedure that differs by area is the breakdown of daily VMT by trip purpose by the population of the area in question.

TABLE 10-1

AVERAGE DAILY LIGHT DUTY TRIPS PER HOUSEHOLD
BY PURPOSE BY POPULATION SIZE

Purpose	LOCATION								
		INCORPORATED PLACES WITH POPULATIONS OF							
	Unincorporated Areas	5000	5000-24999	25000-49999	50000-99999	100000-999999	1000000 & over	Total	All Places
Earning a living	1.5	1.1	1.8	1.4	1.3	1.2	.9	1.4	1.4
Family business	1.4	.8	1.6	1.4	1.2	1.0	.5	1.1	1.2
Educational, civic, and recreational	.4	.2	.5	.3	.3	.3	.2	.3	.4
Social and recreational	.9	.8	1.1	1.0	.8	.8	.3	.8	.8
Vacation	.005 (2 ann.)	.005 (2 ann.)	.008 (3 ann.)	.003 (1 ann.)	.011 (4 ann.)	.003 (1 ann.)	0 (0 ann.)	.005 (2 ann.)	.005 (2 ann.)
All Purposes	4.3	2.9	5.1	4.1	3.7	3.4	1.9	3.6	3.8

Source: U.S. DOT, 1972.

It should be noted that the recommended technique ignores extra loads due to cargo. However, the situation where something other than passengers provides extra weight to the vehicle is likely to be during a social and recreational trip (vacation). Therefore, in many instances, four or more passengers will be in the car during the time that extra cargo is being carried. If this assumption is true, the error produced by ignoring extra loads other than passengers will be small.

10.2 EXTRA LOADS FOR LIGHT-DUTY TRUCKS

It is unclear whether the technique recommended for light-duty vehicles is valid for light-duty trucks. While vans greater than 6000 pounds could be used for car pools, it is unlikely that more than three people could ride in a pickup truck. On the other hand, a pickup truck is more likely to have an extra 500 pound load from carrying cargo than an auto. Therefore, it is probably inappropriate to use the light-duty vehicle methodology for light-duty trucks. In this case, no specific techniques are recommended here. Based on further study, guidance may be available on this topic at a later date.

10.3 TRAILER TOWING TRIPS FOR LIGHT-DUTY VEHICLES

The following subsections describe a method for estimating the percentage of light-duty vehicles towing trailers. Section 10.3.1 describes the data sources, Section 10.3.2 describes the estimation technique, and Section 10.3.3 discusses the advantages and disadvantages of using this method.

10.3.1 Data Sources

The Recreation Vehicle Industry Association, Facts and Trends/1978 report contains sales data for recreational vehicles.

10.3.2 Estimation Technique

The procedure for estimating trailer towing trips starts with determining the number of trailers available for use. Table 10-2 shows recreational vehicle shipments by year from 1961-1978. Of the vehicle types listed, only conventional travel trailers and camping trailers can be towed by light-duty vehicles, and a portion of these are probably being towed by light-duty trucks. It is assumed here that of the trailer types that light-duty vehicles are capable of towing, 80 percent are towed by light-duty vehicles and 20 percent are towed by light-duty trucks.

MVMA (1979) estimates that 117 million light-duty vehicles were registered in 1978. Even if all of the trailers sold from 1961-1978 are still in use, only 3,448,900 trailers would be available for towing. If 80 percent of these trailers are towed by light-duty vehicles, then only 2.4 percent of all light-duty vehicles have trailers available. (This ignores boat towing trailers and trailer rentals.)

This estimation technique further assumes that vacation trips are the times when trailers are used. Table 10-2 should be used to determine the percentage of total trips per day associated with vacation trips. This percentage can then be multiplied by 2.4 percent from the preceding paragraph to estimate the percentage of light-duty vehicle trips/day towing trailers.

The technique presented above can be further refined by using state/local data on trailer and light-duty vehicle registrations. Table 10-3 may be helpful in apportioning recreational shipments to states. In addition, because vacation trips and trailer towing are seasonal, the time of year being analyzed should be accounted for if possible.

TABLE 10-2

RECREATIONAL VEHICLE SHIPMENTS

Year	Total Shipments	Travel Trailers		Truck Campers	Motor Homes			
		Conventional	Fifth Wheel(1)		Conventional	Type B-1 Van Camper(2)	Type B-2 Van Camper(3)	Type C Chopped Van	Camping Trailers
1978	526,300	132,700	27,100	24,700	46,600	19,500	136,400	91,100	48,200
1977	533,900	145,900	22,000	31,900	43,000	40,800	120,000	76,400	53,900
1976	541,100	168,300	21,400	42,000	45,200	36,100	100,000	74,800	53,300
1975	339,600	134,000	16,600	44,300	30,300	26,400	N.A.	39,900	48,100
1974	295,800	113,700	12,600	45,400	26,700	20,800	N.A.	21,400	55,200
1973	528,800	190,500	21,800	89,800	65,300	27,000	N.A.	36,700	97,700
1972	582,979	235,500	15,379	105,100	64,600	23,800	N.A.	28,400	110,200
1971	451,000	190,800		107,200		57,200			95,800
1970	380,300	138,000		95,900		30,300			116,100
1969	400,600	144,000		92,500		23,100			141,000
1968	333,100	115,200		79,500		13,200			125,200
1967	244,430	94,500		61,600		9,050			79,280
1966	219,810	87,300		54,500		5,710			72,300
1965	192,830	76,600		44,300		4,710			67,220
1964	151,000	64,200		34,800		N.A.			52,000
1963	118,600	51,500		26,800		N.A.			40,300
1962	80,300	40,600		16,700		N.A.			23,000
1961	62,600	28,800		15,800		N.A.			18,000

N.A. Not available
(1) To be towed by pickup truck with fifth-wheel hitch mounted in the truck bed.
(2) Panel-type trucks with interior converted to a living area.
(3) Absence of plumbing, heating and 115-volt electrical system distinguish this vehicle from the B-1 Camper.

Source: Recreation Vehicle Industry Association

TABLE 10-3

RECREATIONAL VEHICLE SHIPMENTS BY STATE, 1977

State	Shipments to each State	State	Shipments to each State
Alabama	3,524	Nevada	3,097
Alaska	1,602	New Hampshire	3,203
Arizona	7,688	New Jersey	7,742
Arkansas	3,684	New Mexico	5,499
California	73,304	New York	20,502
Colorado	13,454	North Carolina	8,115
Connecticut	3,524	North Dakota	3,631
Delaware	1,068	Ohio	27,763
Florida	13,935	Oklahoma	11,105
Georgia	6,994	Oregon	17,939
Hawaii	53	Pennsylvania	23,919
Idaho	7,047	Rhode Island	908
Illinois	22,958	South Carolina	2,990
Indiana	18,686	South Dakota	3,470
Iowa	11,586	Tennessee	5,926
Kansas	9,557	Texas	34,330
Kentucky	4,538	Utah	8,489
Louisiana	5,980	Vermont	747
Maine	3,310	Virginia	8,169
Maryland	7,528	Washington	23,011
Massachusetts	6,780	West Virginia	4,698
Michigan	30,379	Wisconsin	12,600
Minnesota	13,988	Wyoming	2,616
Mississippi	2,136	District of Columbia	—
Missouri	10,197		
Montana	4,645		
Nebraska	5,286		
		TOTAL	533,900

Source: Recreation Vehicle Industry Association

10.3.3 Advantages and Disadvantages of the Estimation Procedure

Because trailer towing trips are not well characterized in the literature, it is difficult to recommend any technique for doing so. The technique presented in Section 10.3.2 contains a number of assumptions where little or no data were available. Therefore, any information that is available locally should be used in lieu of the approach described here.

10.4 TRAILER TOWING TRIPS FOR LIGHT-DUTY TRUCKS

The following subsections describe a method for estimating the percentage of light-duty trucks towing trailers. Section 10.4.1 describes the data sources, Section 10.4.2 describes the estimation technique, and Section 10.4.3 discusses the advantages and disadvantages of using this method.

10.4.1 Data Sources

The Recreation Vehicle Industry Association Facts and Trends/1978 report is used to determine recreational vehicle sales.

10.4.2 Estimation Technique

The general procedure for estimating light-duty truck trailer towing trips is the same as that presented for light-duty vehicles in Section 10.3.2. The only difference is that 20 percent of all conventional camping trailers towed are assumed to be towed by light-duty trucks and approximately 20 million light-duty trucks were registered in 1978. In addition, all of the fifth wheel travel trailers shown in Table 10-2 should be assumed to be towed by light-duty trucks. This means that 827,000 trailers are associated with light-duty truck travel. Therefore, 4.1 percent of all light-duty trucks have trailers available.

It is assumed here that Table 10-1 can be used to determine the percentage of trips that are vacation trips for light-duty trucks. To the extent that light-duty truck and light-duty vehicle travel have similar characteristics, this assumption is reasonable.

REFERENCES FOR SECTION 10

Recreation Vehicle Industry Association. 1979. Facts and Trends/1978. Chantilly, VA.

U.S. Department of Transportation. December 1972. Nationwide Personal Transportation Study. Report No. 7. Federal Highway Administration. Washington, D.C.